بسم الله الرحمن الرحيم

Palestine Polytechnic University

College of Engineering & Technology

Mechanical Engineering Department

Graduation Project

Design and Building of Furnace for Testing Fire Rated Doors

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Abstract

Today's our life is full of fire risks, Which encouraged all interesting persons in this field to think of ways of minimizing in our country investment in this field like other manufacturers in other countries and according to then, those doors are carefully designed to provide the appropriate level of fire resistance in the most cost effective light quality package possible.

The lack of testing furnace in the filed of the corresponding organization, (Palestinian Standard Institution); which is responsible for giving the approval certificate for such product and the light cost of testing these products in foreign countries, make it necessary and benefit to design and build a furnace to help us and the interesting persons in performing an extensive fire resistance testing and engineering analyses to show whether those doors are able to perform as claimed or not.

In this project a comprehensive and detailed analysis and discussion of fire resisting doors, testing methods, design and building of the testing devices and furnace in accordance with the national and other international standard, in regards with those products is performed and presented.

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List of Symbols

Q_t	Total load
A	Area
U	Overall heat transfer coefficient
T	Temperature
R_c	The total Thermal Resistant
v	Velocity
Cp	Specific heat at constant pressure
h	The convection heat transfer coefficient
Ç	Emsmistvity of the surface
P	Pressure
Б	Stefan Boltzmann constant
t	Time
ρ	The density of the air
V	The volume of the furnace
R	Ideal gas constant
M	Mass

Chapter One

INTRODUCTION

INTRODUCTION

1.1 General Introduction

The concept of keeping the occupants of some domestic and most commercial buildings safe in case of fire relies upon separating whole buildings(into smaller compartment , there by keeping the fire in the compartments) where it starts, and or creating safe , fire protected routes to aid escape .

This is done by making the walls, ceiling, doors ect. of the compartment or escape route " fire resisting ". Of course, as people go about their day-to-day business they will want pass from compartment to the other, hence the need for fire doors. It is obvious that, for fire safety to be maintained, these door sets must have the same fire resistance as the rest of the compartment or requirements for the door sets will be stated in the appropriate national building regulations and other regulations or requirements in this regards that may be found in the Palestinian standards .

Today, any one can easily notice the increase demand of installing the fire rated (fire resisting) doors in both the private and public establishments especially hospitals, schools, office buildings ect .This demand make some interested people in the industrial section to think in manufacturing such a product .

Super Nimer Industry and Investment Company is the first and the leading factory in our country in this field, this factory which was established since in many years tried to develop and innovate its products using today's technology and was succeeded in producing a different type and models of doors from among is the fire rated doors.

For this and other firms producing such a product, and in order to get the authorized (supervision or quality) certificate from the Palestinian standard institution, they need to build a furnace, to test their products. As there is no such possibilities available in our country, they used to send their products to foreign countries for testing which costs them too much (10 to 15 thousands of dollars for each test in a rate of at least(tow times per year).

The goal of this project is to identify the needed capabilities, design and build of a special furnace to be used in testing the fire rated doors in comparatively economic and efficient way in compliance with the international standards. The major contributions and studies made in each chapter cab be :

The introduction to fire restricting door sets, structure and component of the fire rated door, ironmongery, in tumescent strips, glazing, and glossary of terms that may be encountered in association with fire resisting doors are identified and presented in chapter two.

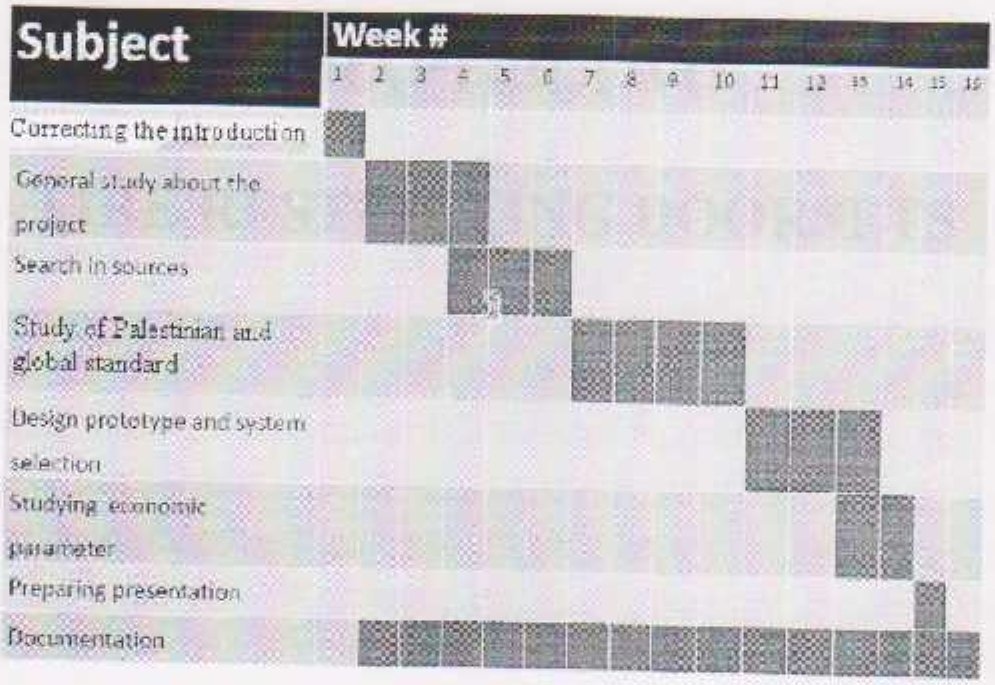
In the next chapter, the national and other international standards and regulations or requirements related to this topic will be explained and studied. The test equipments and testing methods are also discussed. Theory and calculations for the design of the furnace, construction of furnace walls, ceiling, floor and the selection of burner capacity and fuel type used in the furnace are analyzed and discussed in chapter four.

The next chapter will discuss the cost of building the furnace, testing cost and the result obtained from the tests and the capability of getting the supervision certificate for the door from Palestinian Standard Institution.

The appendices give the details of views of the factory and furnace and the catalogues used for the selection of the burner.

1.2 Timetable

Table 1.1: Time Table



Subject	Week #															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Correcting the introduction	▨															
General study about the project		▨	▨	▨												
Search in sources				▨	▨	▨										
Study of Palestinian and global standard							▨	▨	▨	▨						
Design prototype and system selection											▨	▨	▨			
Studying economic parameter													▨	▨		
Preparing presentation															▨	
Documentation		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨

CHAPTER TWO

FIRE RESTRICTING DOORSETS

FIRE RESTRICTING DOORESET

2.1 Introduction

As mentioned before, the need for fire doors is to keep the fire in the zone or the compartment where it starts and preventing it from spreading to the neighbor compartment. Also, the smoke and hot gases are not allowed to pass to the neighbor compartments or escape routes for period of time till the civil defense reaches the place.

2.3 Fire Resistance of Door set

The fire resistance of a door set is specified in terms of minutes, normally expressed as two separate figures. One figure is the time for which, in a fire resistance test, the door set would hold back the passage of flames and hot gases "integrity", the other figure being the time for which the door face that is not exposed to the fire would keep its temperature below a specified value " insulation". Doors are fire resistance tested by installing complete door sets (doors and frames, capable of normal operation) into a wall (normally masonry partition) forming are side of a furnace chamber- The furnace is lit, and its temperature is carefully controlled to comply with the requirements of the standard test method. The temperature reaches around 850C in a half-hour test, and 950C (or about 4 times as a domestic oven) in a one-hour test.

The testing laboratory will issue a test report, with details of the door construction tested and the test results. Theses documents are often referred to as ' certificates', when requested by building control or fire officers. Fire test reports strictly only cover the exact specimens (samples) that were tested and it is, of course, impractical to test all product that are to be sold. For this reason, as we will see in the next chapter, the related standard introduce a "Certificate of Approval" within certain limitations to fully cover the complete range of doors from which the sample was chosen.

2.4 The Fire Resisting Door set

The door set consist of the door leaf itself plus frame and all the ironmongery essential for it to work normally (hinges, door closer and possibly a latch).

Figure 2.1

It is important to realize that a fire door leaf on its own, no matter how well made cannot be expected to provide its full fire resistance performance unless it is properly installed. This will usually require it being hung on hinges that will provide enough support, that will not melt or transmit too much heat through the leaf, in a frame, which is of the appropriate good quality, using the appropriate edge protection to the leaf in the form of in tumescent strips.

2.5 In tumescent Strip:

A strip of noncombustible material, which is installed (in a pre-grooved sleeve) in the edge of a leaf or in a frame reveal around a fire resisting door leaf. Strips are not normally fitted to the bottom edges of door leaves. When exposed to heat (from a fire) the strip swells up(expands at least 10 times its initial thickness), sealing the gaps around the leaf to stop the passage of smoke and hot gases and helping to hold it into the frame when the door closer and/ or latches have stopped functioning. There are various types of in tumescent strips, each of which has its own characteristics when it activates. Appendix 1 shows the specification of strip used in Super-Nimer fire doors. These strips are normally an essential part of any fire door that is to provide 30 minutes fire resistance or more.

2.6 Items of Ironmongery:

Hinges: should be made of metal with a melting point greater than 800C. Figure(2.2) Shows the size and type of hinge used in Super-Nimer doors.

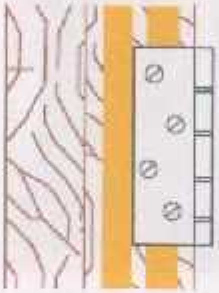


Figure 2.2

Latches: having a square or rectangular case, fully enclosed in a mortice cut from the edge of the door leaf. Latches hold a door closed, and may or may not be lockable.

Deadbolt: A locking mechanism, normally operated by a removable key, may be similar in appearance and installation to knob sets or mortice latches.

Figure (2.3) Shows the type of Deadbolt used in Super-Nimer door.

Figure 2.3

Glazing: Glazin apertures cut in fire doors will affect the behavior of those doors when subjected to a fire (Figure 2.4). As with any fire door, the positions and sizes of these apertures must be within limits that are appropriate to the door. The cast or clear wired glass for use in fire doors must be a fire resisting type.

Figure 2.4

2.7 Fire Door Installation:

The correct installation of fire doors and door sets is fundamental to the overall performance they will achieve in the event of a fire and should only be carried out by competent and experienced professionals.

2.8 Fire Door Construction:

The fire door is constructed from a two galvanized steel sheets of 1.5 mm thickness with a U or Z shaped supports of 1.5 mm thickness in between at 12cm a part. The space between the two sheets is filled with a fire resisting rock wool; the overall thickness of the door leaf is 5 cm. figure 2.5 shows a cross section in the door leaf.

Figure 2.5

The steel sheets are first cut and shaped according to the required size, then the supports are shaped and welded to one face from inside, then the rock wool is placed in between the supports to fill the whole inside of the leaf, then the other face is welded to the supports. Although, width and height of the door leaf is fixed in accordance with the customer request, there are generally some standard sizes of the doors specified in accordance with some regulations.

As not all sizes and shapes are to be tested before being sold, all standards and regulations in this regard suggest that the manufacturer can produce a different size of doors varies from the specimen (sample tested) size with 10 – 15 % in width and height as will be seen in the next chapter.

CHAPTER THREE

NORMS AND STANDARDS

NORMS AND STANDARDS

3 .1 Introductions

The international organization for standardization (ISO) is worldwide federation which deals with the preparation of international standard regarding fire behavior of building materials and building components. The Palestinian Standard Institution (PSI) has prepared a relevant standards. For more convenience some of the national and international standards related to this subject are listed in the list of references.

Those standards lay down definitions, requirements, test conditions and methods relating to fire protection technology for building components from among of them is the fire doors. In this chapter the definitions, requirements and test conditions and methods are briefly summarized and explained to give us an aid in the design of our furnace.

3.2 Definitions

For the purpose of this norm(PSI), the following definitions apply.

Calibration test : Producer to assess the test condition experimentally.

Deformation : Any change in dimension or shape of an element of construction due to structural and /or thermal actions. This includes deflection, expansion or contraction of elements .

Integrity : Ability of separating element of building construction, when exposed to fire on one side, to prevent the passage through it of flames and hot gases or the occurrence of flames on the unexposed side.

Insulation : Ability of separating element of building construction when exposed to fire on one side, to restrict the temperature rise of unexposed face to below specified level.

Neutral pressure plane : Elevation at which the pressure is equal inside the furnace

Separating element : An element that is intended for use in maintaining separation between tow adjacent areas of building in the event of afire.

Supporting construction : That construction that may be required for the testing of some building elements into which the test specimen is assembled, such as the wall into which a door is fitted.

Test specimen : Element or part of building construction (door) provided for the purpose of determining either its fire resistance or its contribuion to the fire resistance of another building element.

National floor level : Assumed floor level relative to the position of the building element in service.

3.3 Test equipment

Equipment employed in the conduct of the test consists essentially of the followings :-

A specially designed furnace to subject the test specimen to the test conditions, control equipment to enable the temperature of the furnace to be regulated, equipment to control and monitor the pressure of the hot gases within furnace, equipment for measuring temperature in the furnace and on the unheated face of the test specimen, equipment for measuring the deformation of the test specimen, and equipment for evaluating test specimen integrity and for establishing compliance with the performance criteria (described later) and for establishing the elapsed time.

3.4 Furnace

The test furnace shall be designed to employ liquid or gaseous fuels [8] and may be designed to assemblies of more than one element can be tasted simultaneously. The type of fuel to be in our design is the LPG gas since it is already available in the factory.

The furnace linings shall consist of materials with densities less than 1000 kg/m^3 [20]. Such lining materials shall have thickness of 50 mm and shall constitute at least 70% of the internally exposed surface of the furnace.

The furnace should be installed in laboratory of sufficient size to prevent the ambient air temperature in the vicinity of a separating element increasing by more than 10 C° above the initial temperature whilst the test specimen is complying with the insulation criterion. The laboratory atmosphere shall be virtually drought – free. The ambient air temperature shall be 20 ± 10 C° at the commencement of the test and it shall be monitored at a distance of 1.0 m ± 0.5 m from the unexposed face under conditions such that the sensor is not affected by thermal radiation from the test specimen and /or furnace.

3.5 Temperature

Prior to the commencement of the test, the furnace temperature shall be less than 50 C°. The commencement of the test shall be considered to be the moment when the program to follow the standard heating curve has been initiated. The elapsed time shall be measured from this point and all manual and automatic systems for measurement and observation shall begin or be in operation at this time, and the furnace shall be controlled to comply with the temperature conditions specified later.

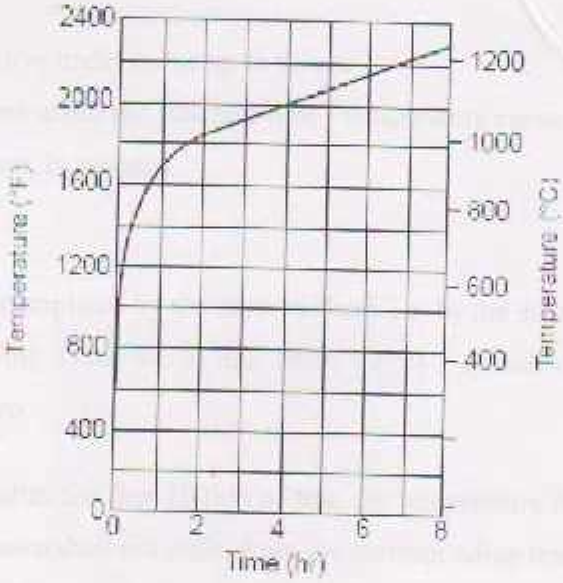
The average temperature of the furnace shall be monitored and controlled such that it follow the relation [6].

$T = 345\log_{10}(8t+1)+20$……………..(3.1)

Where

T: is the average furnace Temperature,(C°).

t: is the time ,(minutes).



Note: The following are the points that determine the curve.

538°C	(1000°F)	at 5 minutes
704°C	(1300°F)	at 10 minutes
843°C	(1550°F)	at 30 minutes
927°C	(1700°F)	at 1 hour
1010°C	(1850°F)	at 2 hours
1093°C	(2000°F)	at 4 hours
1260°C	(2300°F)	at 8 hours or over

Figur 3.1 Standard time temperature curve

As tolerance, the percent deviation (de) in the area of the curve of the average temperature recorded by the specified furnace thermocouples versus time from the area of the standard time / temperature curve shall be within [8]

a) de $\leq$ 15% for $5 < t \leq 10$

b) de $\leq$ 10% for $10 < t \leq 3$

c) de =5 %   for $t > 30$

$$de = \frac{A - As}{As} \times 100\%$$

Where

de : is the % deviation.

A : is the curve under curve up to time t.

As : is the area under the standard time / temperature curve.

t : is the time, in minutes .

All areas shall be completed by the same method, i.e. by the summation of areas at intervals not exceeding 1min for a) and 5min for b) , c) and d) and shall be calculated from time zero .

At any time after the first 10 min of test, the temperature recorded by any thermocouple in the furnace shall not differ from the corresponding temperature of the standard time / temperature curve by more than 100C.

3.6 Plate Thermometers

The Plate Thermometers (PT) has a large exposed surface to make it more sensitive to radiation than a standard thermocouple (T/C). It placed in the furnace so that it receives the same radiation as the specimen. The back is insulated from radioactive influence from the specimen.

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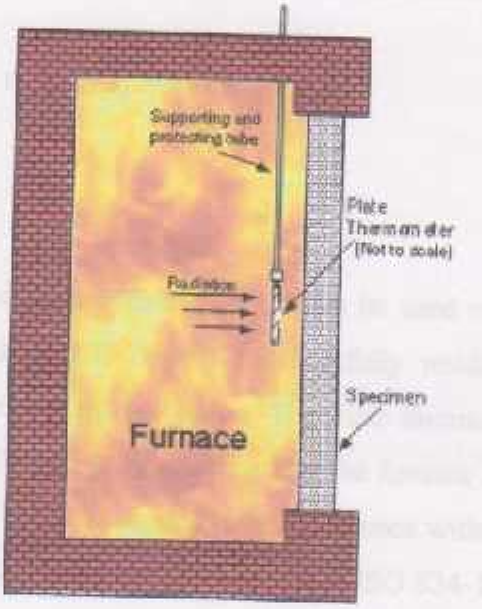
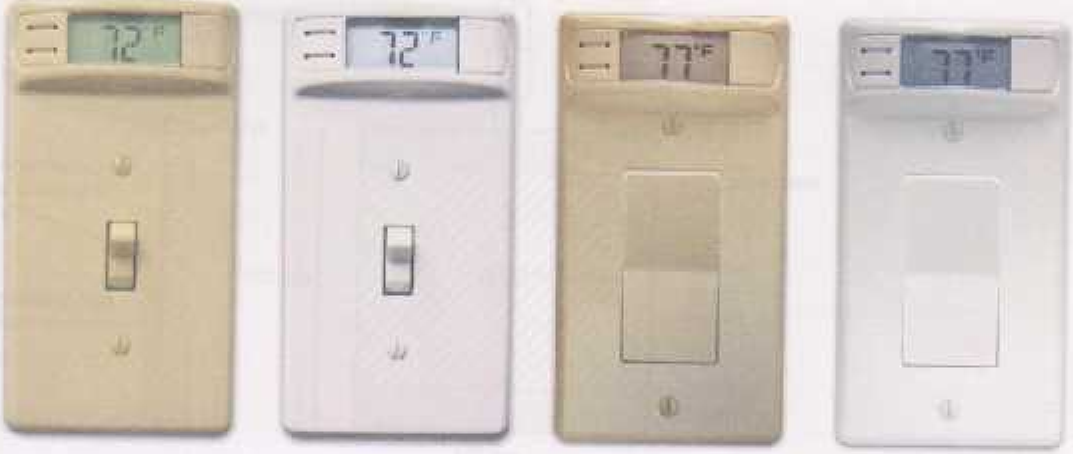


Figure3.2 Plate Thermometers place

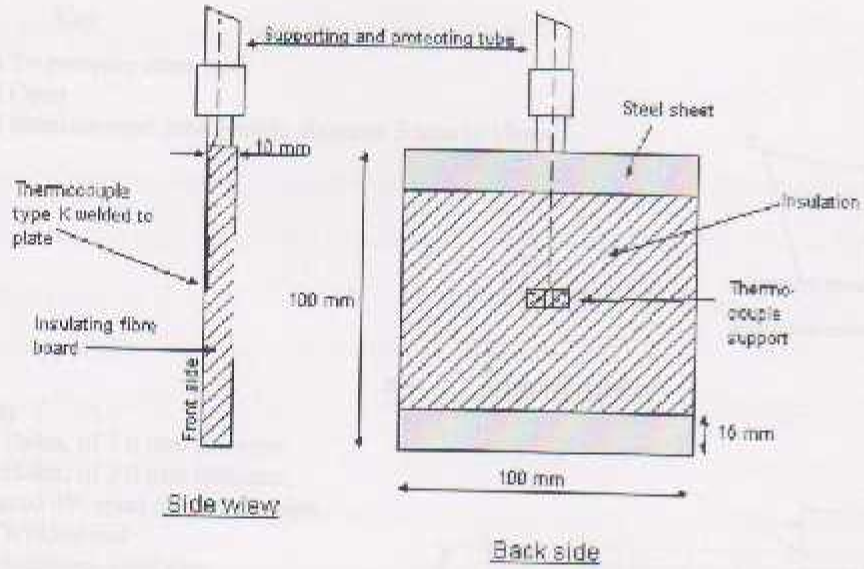
The PT is very thin, only 0.7 mm. Therefore it responses nearly as quickly as a standard (T/C) to changes in furnace temperature. The time response is fast, thus the temperature delay is negligible except readings during the first few minutes of a standard ISO 834-1 test.



Figure(3.3) Plate Thermometers

The PT is a simple and robust instrument. It can be used over and over again like ordinary T/C's. A shielded T/C (type K) is carefully welded or squeezed by mutual strips to a steel plate (see figure below). The plate thermometer is made of Inconel 600 stainless steel. The front side facing into the furnace is treated to give it an emissivity of about 0.8. The PT is mounted in the furnace with a supporting tube. The T/C shall be replaced after 50 h testing according to ISO 834-1 [10].

A mount with an internal thread may then be welded directly to the edge of the plate. A piece of stainless steel tubing of desired length may be screwed into this mount. The in-side diameter of the steel tube should be at least 6.5 mm.



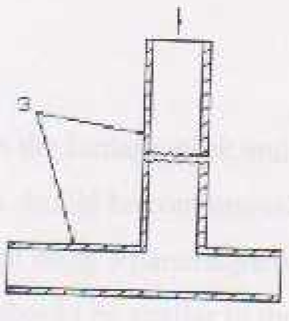
Figure(3.4) Basic design

The PT is placed in the furnace near the specimen with the front-side facing the interior of the furnace. Additional PT's are used to measure variations of the thermal impact along the surface of the specimen .

3.7 Furnace pressure

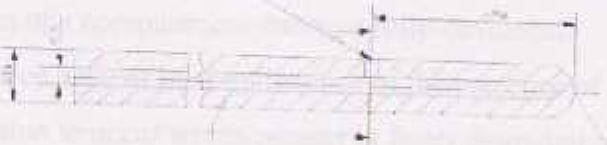
The pressure in the furnace shall be measured by means of one of the designs of sensors shown in the figure 3-2 (a.b).

Key
1) To pressure transducer
2) Open
3) stainless-steel tube (inside diameter 5 mm to 10mm)



a)- "T" shaped sensor

Key
1) Holes, of 3.0 mm diameter
2) Holes, of 3.0 mm diameter,
spaced 40° apart around the pipe
3) Welded end
4) Stainless- steel pipe



b)Type 2 – Tube sensor

Figure (3.4) Pressure – sensing heads

A linear pressure gradient exist over the height of furnace, and although the gradient will vary slightly as a function of the furnace temperature, a mean value of 8 pa per meter height may be assumed in assessing the furnace pressure conditions.

The value of the furnace pressure at specified height shall be the nominal mean value, disregarding fluctuations of pressure associated with turbulence, ect, and shall be established relative to the pressure outside the furnace at the same height. The furnace pressure shall be measured and recorded continuously or at intervals not exceeding 5min at the control point, and controlled for the first 5min from the commencement of the test to +5 Pa and for 10min to + 3Pa . The furnace shall be operated such that a pressure of zero established at a height of 500mm above the notional floor level. However the pressure at the top of the test specimen shall not be greater than 20Pa, and the height of the neutral pressure plane shall be adjust accordingly[15].

3.8 Furnace oxygen concentration

Furnace oxygen concentration should be measured in the furnace stack and maintained at greater than 6% during the test. Gas samples should be continuously drawn out of the duct through a sampling line and measured using a paramagnetic type oxygen analyzer. The recommended sampling probe should be similar to the sampling probe used in duct measurements of hood calorimeters. Arrange of oxygen levels may exist during the course of compartment fire this may vary from zero to several percent in the upper portions of a compartment during a fully-developed fires. from a fire resistance perspective. One of the implications of the presence of oxygen is that allows chare oxidization to occur which present in faster degradation of material. This has been noted a furnace testing, it is also desirable to have excess oxygen within the furnace to allow combustible test articles to burn as they could in compartment firesp[9].

It is recommended that the oxygen concentration to during the test be above 6% during the furnace test. This was developed best on oxygen concentration requirements in other fire resistance test standards as well as oxygen concentration measured in the upper-layer of fully-developed fires. The fire resistance standards ISO 834-1 requires that minimum oxygen concentration of 4% be maintained within the test furnace during the course of the fire test[9].

3.9 Furnace Velocity Distribution

While it is important to crate realistic convective environment in the furnace, it is difficult to conduct meaningful velocity measurements in the furnace where the flow is expected to be complex, no velocity measurements recommended inside the furnace.

3.9 Gas temperature measurements

Specimen should be measured using aspirated thermocouples. Gas temperature should be measured at each location where a temperature profile is being measured. Aspirated thermocouples should be placed as close as possible to the test article surface.

Heat-transfer analyses of the assembles may require the use of the gas temperature on both sides of the test article. Depending on the analysis, gas temperature may be needed to calculate the appropriates heat-transfer coefficient and may be used in defining the boundary condition.

Gas temperature should be measured as close as possible to the boundary surface to obtain a measure of the temperature affecting the convective heat-transfer at the surface. Using aspirated Thermocouples with high aspiration velocity provides a measure of the actual case temperature without the effects of radiation from the surrounding. This gas temperature measurements well be used to support heat-transfer calculations but will not be used to control furnace conditions.

3.11Furnace Lining Material

All interior furnace surfaces should be lined with a ceramic fiber material.

Fire resistance furnaces have traditionally been lined with high temperature refractory brick materials commonly used in commercial furnaces. These refractory bricks are a low-density material (approximately 50 lbs/ft3 (775 kg/m3) and have a maximum operating temperature of approximately 2600°F (1425°C). When used in a fire resistance furnace, the refractory brick has a high thermal inertia, relative to the fire exposure period (typically 1 to 2 hours)[9].

This thermal inertia results in the refractory brick absorbing significant amounts of heat during the initial portions of the test (first 15 minutes), producing a dominantly convective heat environment within the test furnace.

The furnace environment within the furnace transitions to a highly radioactive environment once the brick temperature equalizes with the furnace air temperature.

To minimize the heating time of the furnace apparatus, thus resulting in less heat loss/absorption to the furnace walls, lining the inside surfaces of the furnace with a ceramic fiber insulating material is recommended. Experimental studies reported by Harada et al. (1997) demonstrated that a key aspect of the furnace environment was the absorption coefficient of the furnace gas, which is a function of gas temperature and the composition of the furnace gas[9].

Tests conducted in a furnace lined with a ceramic fiber insulation material demonstrated small variation in measured test specimen temperatures as a function of furnace depth, with variations decreasing as the furnace depth increases. A similar trend was observed in furnaces lined with refractory brick, however, the temperature measurement variations increased for the similar exposure conditions. These tests demonstrate the ability of the ceramic fiber to heat up faster, resulting in a more uniform exposure temperature, and the development of a radiation dominant furnace environment.

Analysis conducted by Babrauskas and Williamson (1978) support the use of ceramic fiber insulation materials used as the lining materials on developing a more uniform heat flux within the test furnace which results in improved furnace control[9].

3.12 Minimum furnace depth

Studies conducted by Harada et al. (1997) and Fromy and Curt at (1999) investigated the effect of furnace depth on the furnace environment. The work by Harada et al. (1997) evaluated furnace depth of 0.6 ft,(0.17 m), 1.6 ft (0.5 m), 3 ft (0.95 m), and 9.8 ft (3.0 m)[9].

The results of the tests indicated that as the furnace depth increased, the radioactive heat increased proportionally.
Furnace depth slightly greater than 4 ft (1.2 m) showed a convergence in the predicted specimen Surface temperatures the non-dimensional furnace depth parameter, relates the furnace environment with the furnace depth. As depth increases, the exposed face specimen temperature uniformity converges.

Fromy and curtat (1999) reported the results of testing conducted in furnaces having depth of 2 ft (0.6 m), 4 ft (1.2 m), and 5 ft (1.5 m). As the depth of furnace increased, variations in the exposed surface temperature decreased. These results indicated that as the depth of the furnace increased, the furnace environment volume become more uniform, and local effect from the burners and re-radiation from the furnace walls decreased[9].

By increasing the non-dimensional furnace depth factor, a more uniform furnace environment can be produced. The studies reported above indicate that minimum furnace depth of 4 ft (1.2 m) would be expected to produce a uniform furnace environment which will reduce uncertainties and variability in the test conduct related to furnace construction.

3.11 Secondary Air Capability

when necessary, a means for providing secondary air should be provided such that the minimum oxygen content within a furnace is not less than 6%.

Maintaining a minimum oxygen concentration within the test furnace is desired to produce condition that could be obtained in compartment fire to support the combustion and char oxidation of combustible test samples such as wood. A minimum oxygen concentration of 6% was determined to be reasonable. A secondary air flow path into the furnace may be required to maintain the oxygen level, especially in case where the test article is combustible. Sufficient oxygen depletion due to burning test article[9].

3.12 Exhaust control

A mean for controlling the internal furnace pressure (e.g., damper in exhaust stack) should be provided.

Fully-developed fires will always produce a positive pressure gradient across ceilings and majority of the boundary height relative to ambient conditions. In these areas of positive pressure, hot gases are driven through small opening that develop in the assembly causing damage to the internal portions of the assembly. Got gas migration through the assembly may also give rise to ignition on the unexposed Side of the assembly in these local areas of weakness. As a result, it is recommended that furnace tests be performed with a positive furnace pressure so that the effects of hot gas transmission through the assembly can be observed.

Furnaces should contain a means for controlling the pressure inside furnace during the test. As described in the above, a positive furnace pressure (relative to the laboratory) will be maintained across the entire test article in both vertical and horizontal tests. In vertical tests, the neutral plane in the furnace needs to be maintained at the bottom of the test article to have the entire test article at positive pressure. There should be no limit on the pressure at the top of the test article; for a 2.4-m (8-ft) high-test article the pressure at the top will be approximately 18-22 Pa depending on the gas temperature. In the horizontal tests, the furnace should be maintained at 20 Pa during the entire test. The damper system should be designed and demonstrated to be the capable of meeting these requirements, with some lead way to account for leakage throw the assembly[9].

CHAPTER FOUR

LOAD CALCULATION

CHAPTER FOUR

LOAD CALCULATION

4.1 Furnace Dimensions and Design Conditions

The furnace shall be capable of subjecting one side of the specimen (door) to the heating conditions specified in ISO 834, and the furnace temperatures shall measured with respect to the specimen and controlled within the tolerances specified ISO 834. The complete assembly to be rested shall be full site.

The maximum dimensions of the fire-rated door produced Super Dimmer and to be rested is 2 × 2.1m for a single leaf (wing). So in order to reduce the cost of building the furnace and to be able to accommodate this door in the furnace wall, the suggested furnace dimensions with the a agreement of the Palestine Standard Institution, were chosen to be (1.2 × 2.5 × 2)m (see fig 4.1)

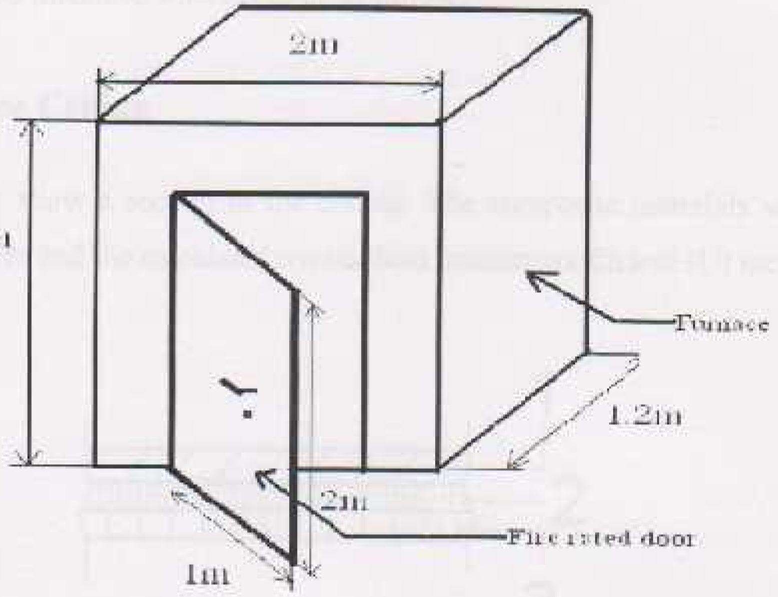


Figure 4.1furnece diminution

4.2 Furnace Conditions:

The test shall be performed on a complete door assembly as intruded to be used in practice incorporating all hardware and other equipment . Hardware includes such items hinges, late lies , door handles, locks, keyholes, letter plates, sliding year, closing devices, electrical wiring and any other items which may influence the performance of the door being tested. The door shall be tested in a wall of the type in which it is intended to be used, particularly when it forms part of a prefabricated or industrialized system. When this cannot be specified, the wall may be of concrete or brick having a thickness of (Ref. no) (ISO 3008-1976 (E))

- about 100mm for a test having an anticipated duration of 2h or less.
- about 200mm for tests of longer aluration.

For the case four furnace in this project, the walls, floor, and ceiling compositions and thickness selected to be as follows.

4.2.1- Furnace Ceiling

Figure 4.1 show a section in the ceiling. The composite materials with their thermal properties and the calculated overall heat transfer coefficient (U) are listed in Table (4.1)

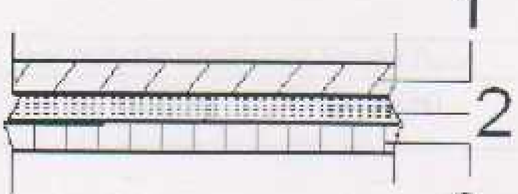


Figure 4.1 Construction of the ceiling.

Table 4.1: Overall heat transfer coefficient for the ceiling

Material	K(W/m.°C)	ΔX(m)	R(m². /W)
Outside air film	--	--	0.10
1-Itong block	0.45	0.05	0.105
2-Rook wool	0.04	0.05	1.25
3-Fire brick	0.47	0.05	0 .106
Inside air film	--	--	0..02
U=.46 (W/ m².°C)			

4.2.2- Furnace Floor

Figure (4, 2) shows a section in the floor. The floor composite materials with their thermal property and the calculated overall heat transfer coefficient (U) are listed in Table(4,2) .

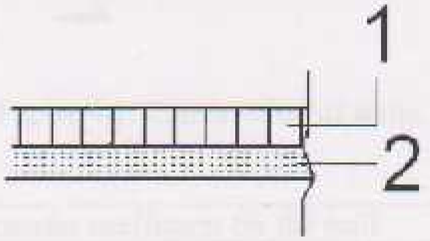


Figure 4.2: Construction of the floor

Table 4.2: Overall heat transfer coefficient for the floor

Material	K(W/m.°C)	ΔX(m)	R(m².°C /W)
Outside air film	--	--	--
1-Rook wool	0.04	0.05	1.25
2-Fire brick	0.47	0.05	0.106
Inside air film	--	--	0.15
U=.65(W/ m². °C)			

4.2.3- Furnace Walls

Figure (4.3) shows a section in the wall, the construction of the wall was chosen from fire bricks and insulating material of Rock wool. With their thermal properties and calculated overall heat transfer coefficient are as shown in Table (4.3).

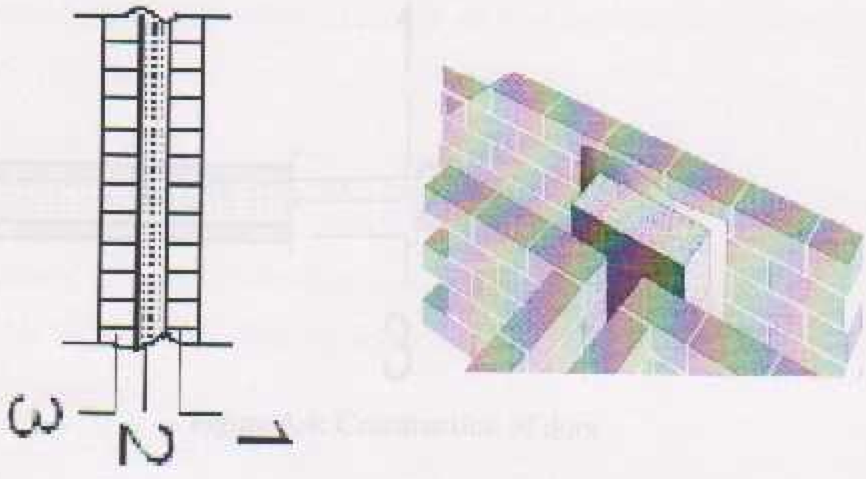


Figure 4.3: Construction of walls.

Table 1.6: Overall heat transfer coefficient for the wall

Material	K(W/m. Ċ)	ΔX(m)	R(m². °C /W)
Outside air film	--	--	0.06
1-Fire brick	0.47	0.05	0 .106
2-Rook wool	0.04	0.05	1.25
3-Fire brick	0.47	0.05	0.106
Inside air film	--	--	0.31
U=.504(W/ m².°C)			

4.4.4- U-value for the door

The door is manufactured from two layers of galvanized steel sheets of 1.5mm thickness with 4.7mm thickness of Rock wool in between (fig .4.4) Table(4.4) shows the thermal properties and the calculated U-value of the door.

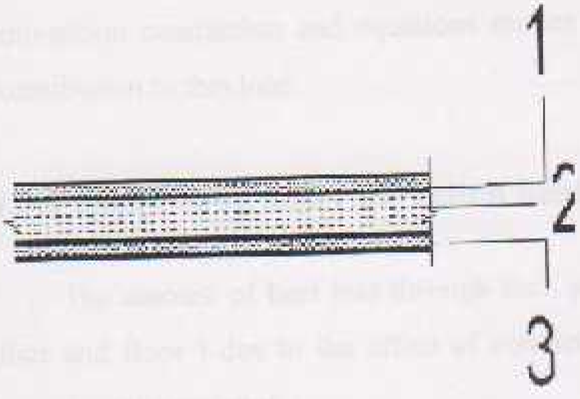


Figure 4.4: Construction of door

Table 4.4: Overall heat transfer coefficient for the door

Material	K(W/m.°C)	ΔX(m)	R(m². °C /W)
Outside air film	--	--	0.06
1-Steel	45	0.0015	0.00005
2-Rook wool	0.04	0.047	1.175
3-Steel	45	0.0015	0.00005
Inside air film	--	--	0.31
U=.714(W/ m².°C			

4.3 Heat loss calculation

In order to decide on the capacity of burners hat will be used to provide and achieve the standard temperature-time curve complying with the International standard requirements; the total heat loss from the furnace is to be calculated.

In addition to the sensible heating of air within the furnace, the three usual convention conduction and equations modes of heat transfer will make the major contribution to this load.

4.3.1 Convection and conduction heat loss

The amount of heat loss through each partition of the furnace (walls, ceiling, door and floor) due to the effect of coniviction and conduction will be calculated according the equation :

$Q = U\ A\ \Delta\ T$.............(4.1)

Where:

Q_c: heat loss through partition (W)

U : overall heat transfer coefficient $\{\frac{W}{m^2 c^o}\}$

A : surface area for each partition $\{ m^2 \}$

T : Temp. difference across the partition(C°)

The overall heat transfer coefficient U, for each partition is calculated according to the following radiation {listed in the previous tables for the different partitions} :-

$$U = \frac{1}{R_{th}} \text{...}(4.2)$$

$$wher \rightarrow R_{th} = \frac{1}{h_o} + \frac{\Delta xi}{ki} + \frac{1}{hi} \text{.................}(4.3)$$

Where

R_{th} : the total thermal resistance of the partition(m^2 °c/w)

ΔXi : thickness of layer (m).

ki : thermal conductivity of composite material (w/mc^{o})

hi : inside connection film coefficient (w/mc^{o})

h_o: outside connection film coefficient (w/mc^{o})

A simple calculation of the conducted heat loss throw one of the walls is shown below:-

$$Q_w = U_w A_w \Delta T \text{.......................................}(4.1)$$

U_w : was calculated using equation (4.2) as :-

$$U = \frac{1}{R_{th}} \text{...}(4.2)$$

$$R_{th} = \frac{1}{h_o} + \frac{\Delta xi}{ki} + \frac{1}{hi} \text{...............................}(4.3)$$

Where Ri = .10 (wc^{o}/w) .

R_o= .02 (wc^{o}/w) .

Δx for each composite layer is shown in Table (4.1)

So

$$R_{th} = .1 + \frac{0.05}{0.47} + \frac{0.05}{0.04} + \frac{0.05}{0.47} + .02$$

$$R_{th} = 2.182 (w/mc^{o})$$

So

$$U_w = \frac{1}{R_{th}} = \frac{1}{2.182} = 0.46(w/m^2c^o)$$

A_w = width * length =2.64m^2

$\Delta T = T_i - T_o$

where

T_i = inside temperature, the temperature of the furnace which is a function of time:-
$T_i = 345\log_{10}(8t+1)$

T_o = outside temperature, the temperature of the surrounding of the furnace which taken to be the temperature of the room in which the furnace is located and taken to be 20C°.

Therefore,

$$Q_c = 1.2[345\ \log_{10}(8t+1) + 20]$$

The heat loss due to convection and conduction from the other walls and partitions (ceiling, floor, door)are calculated in a similar way and the total heat load throw the all partitions of the furnace will be :-

$$Q_c = 12.104[345\log_{10}(8t+1) + 20]$$

4.3.2 Radiation heat loss.

The radiation heat loss calculation is very complex it is depends on many variables and it differs as the depth of furnace increased, using the direct radiation equations heat loss will be estimated as:-

$Qrad= A*\zeta*\delta*(T_1^4-T_2^4)$ ---------------- (4.4)

Where

A: The serves area (m^2).

ζ: Emissivity of the surface (dimensionless)

Б: Stefan Boltzmann constant (W/ m^2K^4)

T: Temperate (K)

For $A=23\ m^2$

$\zeta=.74$

$Б=5.669*10^{-8}$

$T_1=(345\log10(8t+1)+(273)K$

$T2=20K$

$$Qrad=96.5*10^{-8}((345\log_{10}(8t+1)+273)^4-(293)^4))$$

The total heat losses due to radiation depend on time as the equation describes the total load by radiation.

4.3.3 Sensible Heat

It is the amount of heat that is required by the burner to rise the temperature of the air that is in the space of the furnace, because it is not easy to fined the mass of air, and at this low pressure and high temperatures the state of ideal gas is assumed for the air in the furnace and can be estimated as :

Qsen. = m cp ΔT................ (4.5)

Where :-

Q_{sen} : Amount of sensible heat [kj].

m : Mass of the air [kg].

C_p : Specific heat of air at constant pressure [$kJ / kmol.k^{\circ}$] .

ΔT : Temperature rise of air from 293K to1223K.

Since the Mass at the air that is in the furnace we can calculate it by the relation .

m= ρ.v......................(4.6)

where.

ρ: the density of the air (Kg/m3)

v:the volume of the furnace(m3)

according to cp it change according to temperature change from 1.004(kj/Kmol.k) atT_1equ 793Kto1.152(kj/Kmol.k)atT_2equ1223K.

according to sensible heat it change according to time since the temperature depend on time so the ideal gas equation.

pv=mRT....................(4.7)

m=pv/RT...................(4.7)

Where

P_1: The pressure in the furnace 10^5 pa

P_2: The pressure in the furnace $5 \cdot 10^5$ pa

v:The volume of the furnace(m3)

M:Mass of the air (Kg/s)

R: Constant eq 8.314(Nms/ KmolK

T: Temperature rise of air [k]

The Sensible heat load can be calculation by used the fooling equation.

$$Qsen = m_2 * C_{P2} * T_2 - m_1 * C_{P1} * T_1 \text{ ....(5.4)}$$

$$Qsen = C_{P2} * P_2 * V/R - C_{P1} * P_1 * V/R \text{ ....(4.8)}$$

$Qsen = .11 * 10^5$ kj

The period time for testing is 1.5 a hour and the load in Watt is 122kw.

The following equation describe the total load, as function of time .the figure below (fig 4.4)represent this graphically, and from this graph or equitation, and after choosing the testing time required the capacity of burners can be determined. The testing time depends on maximum fire-rated period require by the product.

$$Qt = 12.32(354\log_{10}(8t+1)) + (23 \times 0.78 \times 5.669 \times 10^{-8})((345\log_{10}(8t+1)+273)^4 - (298^4)) + 122$$

In Super Nemer was taken to be 1.5 hour. The calculation and selection of burner is pressed 6 burners are selected to give the amount of heat.

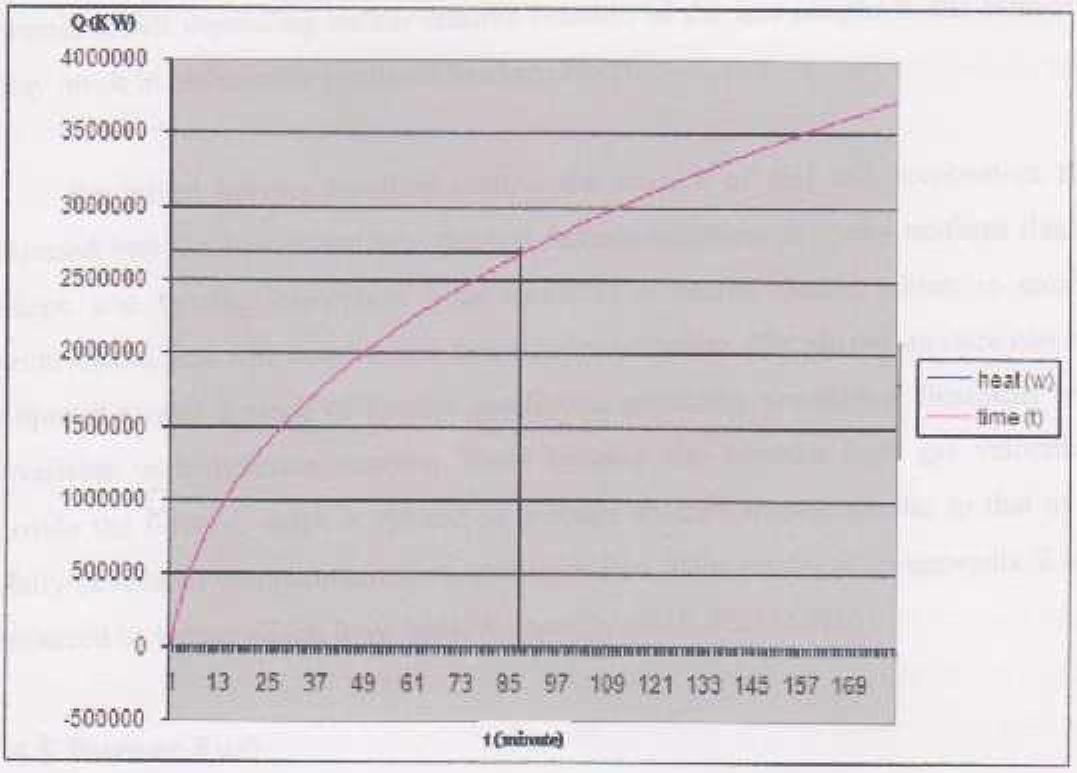


Figure (4.4) The relation between(Q&t)

4.4 Type of Burner

Pre-mixed burners should be used in all fire resistance furnaces.

Two basic types of burners are currently used in existing fire resistance test furnaces; premixed burners and diffusion burners. Control of the furnace temperature using diffusion burners typically involving adjusting the raw gas flow into the furnace to maintain the required temperature level. With this type of burner set-up, openings into the test specimen may require flowing additional raw gas into the furnace to maintain the furnace temperature. This can result in incomplete combustion within the test furnace. The installation of the "burners" in the test furnace requires careful placement as these burners typically produce a large flame plume, which depending on the relative location of the test sample to the burners, may result in undesirable localized heating effects.

Pre-mixed burners carefully control the amount of fuel and combustion air injected into the burner and into the test furnace resulting in a very uniform flame shape and heating capability. This result in a burner flame, which is easily controllable, and with combustion that is more complete. The air-gas mixture can be adjusted to suit a range of furnace conditions, providing operational flexibility not available with diffusion burners. These burners also produce high gas velocities inside the furnace, witch is desired to produce an environment similar to that of a fully-developed compartment fires, and from Eco Flam catalogue in appendix 7 we selected he burner which have 500KW capacity (MULTCALOR45).

4.5 Burner Fuel

Propane gas should be used as the furnace fuel in all fire resistance furnaces.

Furnaces in the U.S. and in Europe use a variety of fuels to provide the heat input into the test furnace. In the U.S. gaseous fuel, either natural gas or propane, is used as the burner fuel. In some overseas furnaces, liquid fuels (heavy oil or kerosene) are used. Testing conducted by Cooke (1994) evaluated the thermal environment impact on a calibration sample in a number of furnaces located overseas. Two of the furnaces used natural gas as the burner fuel and one furnace used oil. The results of the testing did not specifically focus on the impact of the burner fuel on the furnace environment and performance of the calibration specimen, however, it was noted that the oil-fired furnace produced a more thermally-severe furnace environment compared to the natural gas fired environment[9].

Numerical studies conducted by Sultan and Denham (1997), Sultan, Harmathy, and Mehaffey (1986), and Sultan (1996) all recognize that the absorption coefficient for the furnace hot gasses will vary with the type of burner fuel[9].

Typically, the absorption coefficient is lower for gaseous fuels and higher for liquid fuels. As the furnace gas absorption coefficient increases, the severity of the exposure increases correspondingly. Systematic studies of propane versus natural gas do not appear to be available in the literature. Such a study would be of value to the fire resistance testing community.

Recognizing that liquid fuels will produce a more severe fire exposure, there exist practical operational and safety issues related to using liquid fuels sprayed into a closed environment. The spraying of a liquid fuel into a furnace may result in the build-up of residue on the furnace walls as a function of time, which may lead to increased maintenance costs. Safety systems would need to be implemented to insure the spraying system can be adequately secured upon termination of a fire test. Commercial gas-fueled burners are readily available with appropriate safeguards for ensuring gas flow is secured upon termination of a test.

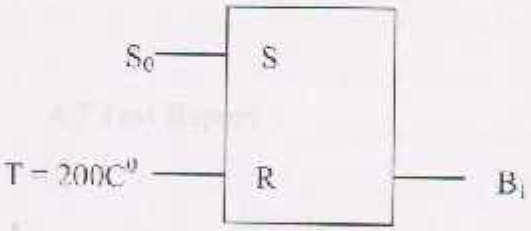
The burning of liquid fuels may not be as clean as gaseous fuels, therefore, requiring additional environmental considerations for the utilization. Many municipalities already contain the infrastructure to provide natural gas via underground supply lines or liquid propane via truck. Of the two, storage of liquid propane, used with an appropriate vaporization system, can maximize the on-site storage capability for conducting large-scale furnace testing.

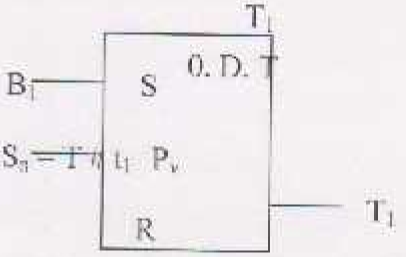
4.6 Fire Control System:

As a result of calculation ,the number of burner to active this load was found to be 6 burners those burners are to set firing in sequence .the first burner with the capacity of 500kw will give this amount within 4.5min ,the next burner with same capacity is to start firing the next 13.5 minutes with firer Contents so on .

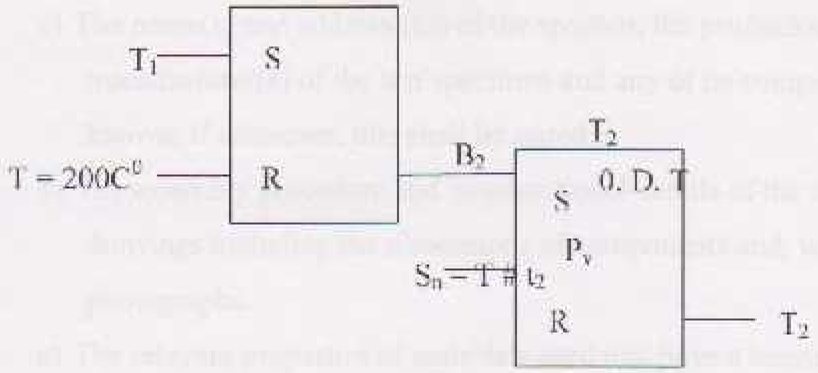
The control system for the commotion of burners using programmable logic controllers (PLC) will be as flows.

The first Burner will be switch on with the starting process and then the other will be switch on as shown:





S₀ : the starting process.
B₁: the first Burner.
T = 200: temp. From temp. Sensor which let the process is complete at it.
T₁: on delay timer set where B1 is cured.
t₁: time where the first Burner has full capacity (from capacity curve).



B2: 2nd Burner.
T2, t2: time for 2nd Burner to achieve its capacity (from capacity curve) & it will be open the 3rd Burner.

All timers will be on Delay timer. And so on for other Burners (How many Burners it have?)

4.7 Test Report

The test report shall carry the following statement in a prominent position.

"This report provides the constructional details, the test conditions and the results obtained when a specific element of construction was tested following the procedure specified in ISO 834-1. Any significant deviation with respect to size, constructional details loads, stresses, edge or end conditions may invalidate the test result."

a) The test report shall include all important information relevant to the test specimen and the fire test including the following specific items and those items required by the test standards for the individual elements:

b) The name and address of the testing laboratory, any unique reference number and the test date.

c) The name(s) and address (es) of the sponsor, the product(s) and the manufacturer(s) of the test specimen and any of its component parts, if known; if unknown, this shall be stated.

d) The assembly procedure and constructional details of the test specimen, with drawings including the dimensions of components and, where possible, photographs.

e) The relevant properties of materials used that have a bearing on the fire performance of the test specimen together with the method of their determination, including, for example, information concerning moisture content and conditioning where appropriate.

f) For load bearing elements, the load applied to the test specimen and the basis for its calculation.

g) The support and restraint conditions used and the rational for their selection.

h) Information concerning the location of all thermocouples, deformation and pressure measuring devices, together with a graphical and/or tabular depiction of data obtained from these devises during test.

i) A description of significant behavior of the test specimen during the test period, together with the determination, on the basis of the criteria in clause 10, of the end point of the test.

j) The fire resistance of the test specimen expressed as specified in clause 12.

k) For asymmetrical separating elements, the direction in which the test specimen was tested and validity of the test result if the structure is exposed to fire on the opposite side.

4.8 SUMMARY OF RECOMMENDATIONS

4.8.1Furnace Instrumentation Recommendations

1- Recommendation: Furnace Temperature Control – Plate thermometers should be used to measure furnace temperature and control the furnace exposure. There should be nine plate thermometers equally distributed across the test specimen surface. Plate thermometers are typically placed 0.10 m (4 in.) away from the sample; however, a larger spacing is desired to prevent them from potentially being damaged by failing test articles. Testing needs to be performed to demonstrate that a larger spacing does not affect the thermometer measurement.

2- Recommendation: Furnace Differential Pressure – Tests should be performed with a positive furnace pressure (relative to laboratory conditions) across the entire test article. All furnace pressures should be measured using the tube sensor provided in ISO 834 and EN1363-1. In a vertical furnace, pressure should be measured at the bottom and top of the test specimen. The neutral plane in the furnace should be maintained at the bottom of the test specimen with no limit on the pressure at the top of the specimen. In a horizontal furnace, the furnace pressure should be measured at one location and maintained at 20 Pa. Pressure tube sensors should be located at the same distance away from test articles as the plate thermometers.

3- Recommendation: Furnace Oxygen Concentration – Furnace oxygen concentration should be measured in the furnace stack and maintained at greater than 6% during the test. Gas samples should be continuously drawn out of the duct through a sampling line and measured using a paramagnetic type oxygen analyzer. The recommended sampling probe should be similar to the sampling probe used in duct measurements of hood calorimeters.

4-Recommendation: Unexposed Side Temperatures – The unexposed side temperatures should be measured with a thermocouple placed between the specimen and a noncombustible, insulating pad. The insulating pad should be a low density, low thermal conductivity material with known thermal properties. The pads should be approximately 0.15 m (6 in.) square and 25 mm (1 in.) thick and placed in at least three locations that provide a range of heat-transfer performance.

5- Recommendation: Total Heat Flux off the Unexposed Side – The total heat flux off the unexposed side of the assembly should be measured using a Schmidt-Boelter type water-cooled total heat flux gauge. At a minimum, a heat flux gauge should be placed near the center of the test article and as close as possible to the unexposed side. In cases where the assembly contains a transparent section, a heat flux gauge should also be placed at the center of the transparent section as close as possible to the unexposed surface.

6- Recommendation: Furnace Velocity – Velocity measurements inside the furnace should not be made.

7- Recommendation: Temperature Profile through Test Specimen – Temperatures should be measured through the thickness of the test assembly at locations that are representative of the different heat-transfer paths within the assembly. Repeat temperature profiles are recommended in case some thermocouples fail during the test.

8- Recommendation: Gas Temperature Measurement – Gas temperatures on the exposed and unexposed side of the test specimen should be measured using aspirated thermocouples. Gas temperatures should be measured at each location where a temperature profile is being measured. Aspirated thermocouples should be placed as close as possible to the test article surface.

4.8.2 Furnace Operations Recommendations

9- Recommendation: Furnace Time-Temperature Exposure Curve – The furnace time-temperature exposure should linearly increase to 1200°C in six minutes and remain constant at 1200°C for the remainder of the test.

10- Recommendation: Calibration Test – A calibration test should be conducted with a noncombustible boundary containing instrumentation to quantify the thermal exposure. Instrumentation installed in the boundary should include total heat flux gauges and calibration boards instrumented with thermocouples. Instrumentation should be installed in at least five locations (center of each quadrant and center of the boundary) to quantify the furnace exposure. The calibration test should be performed for one-hour using the required furnace exposure and instrumentation.

11- Recommendation: Furnace Lining Material – All interior furnace surfaces should be lined with a ceramic fiber material.

12- Recommendation: Minimum Furnace Depth – The minimum furnace depth should be 4 ft (1.2 m).

13- Recommendation: Burner Fuel – Propane gas should be used as the furnace fuel in all fire resistance furnaces.

14- Recommendation: Type of Burner – Pre-mixed burners should be used in all fire resistance furnaces.

15- Recommendation: Secondary Air Capability – When necessary, a means for providing secondary air should be provided such that the minimum oxygen content within a furnace is not less than 6%.

16- Recommendation: Exhaust Control – A means for controlling the internal furnace pressure (e.g., damper in exhaust stack) should be provided.

17- Recommendation: Thermal Properties of Materials – The thermal and physical properties of materials in the test article assembly should be measured. Thermal properties (conductivity, specific heat capacity, heat of decomposition) should be measured at temperatures as close to the highest temperature the material is expected to reach during the test. Physical properties (density, moisture content, expansion/contraction, decomposition kinetics) should also be measured as a function of temperature up to temperatures the material is expected to reach during the test. Thermal property test should be performed on materials taken from the same lot of materials used to construct the test article.

References:

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3. Lattimer B., and Ouellette J., (2004), "Thermal Properties of Composites for Heat-transfer Modeling during Fires," Proceedings of SAMPE 04 Conference, Long Beach, CA.

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Shielded Thermocouples," Fire Technology, 42, pp. 253–267.

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8.10.1.1.1.3 ASTM D 198–05a (2005), Standard Test Methods of Static Tests of Lumber in Structural Sizes, American Society for Testing and Materials, West Conshohocken, PA.

9. http://fire.nist.gov/Almand_NIST_SFPE%20_IR%207133.pdf

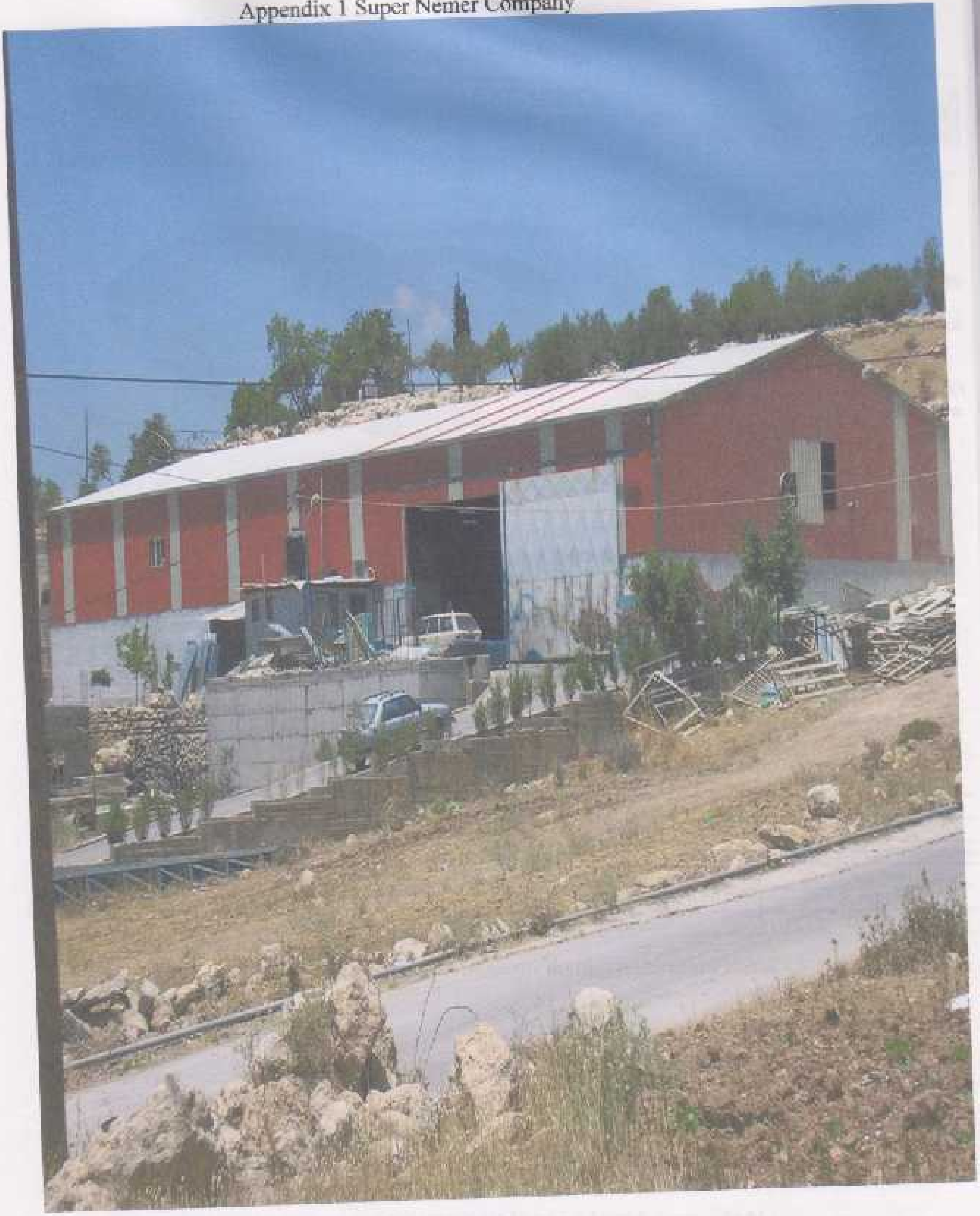
10 http://www.promat-tunnel.com/idprt004.htm#

11. http://www.promat-tunnel.com/en/2008-Efectis-R0695_Fire_testing_procedure_concrete_tunnel.pdf

12 PS 852- part 1
13 Fire Door and smoke door assemblies : swinging Fire Doors.
14 PS 853 – part 1.
15 PS 853 – part 2.
16 DIN 4102 – part 5 : Fire Behavior of Building Materials and Building Components.
17 DIN 4102 – part 15 : Fire Behavior of Building Materials and Building Elements.
18 ISO 3008 -1976 (E)Fire- resistance tests – Door and Shutter assemblies.
19 ISO / TR 5925-2 : Fire tests - smoke control Door and Shutter assemblies.
20 ISO 834-1 : Fire- resistance test- Elements of building construction.

APPENDICES

Appendix 1 Super Nemer Company



Appendix 2 Flexible in tumescent seal

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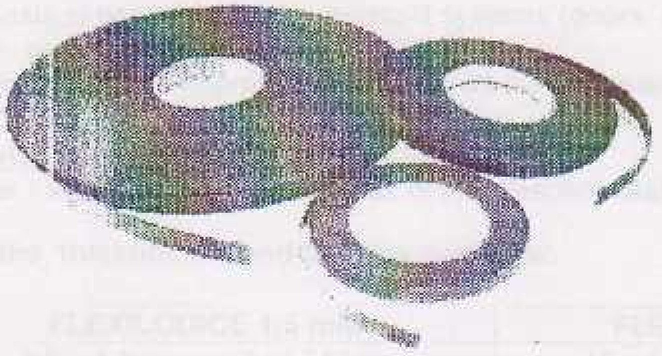
FLEXILODICE

Flexible intumescent seal

Technical data sheet

New Product



PRODUCT DESCRIPTION

FLEXILODICE is a flexible intumescent seal based on graphite. In case of fire, the intumescent material included in the thermoplast support is expanding at least 10 times its initial thickness.
The microporous layer formed durin the expansion provides an effective barrier to the passage of fire, hot gases and hot smokes.

FEATURES

The intumescent seal FLEXILODICE holds the following properties :

- very flexible,
- resistant to moisture and carbone dioxide,
- formation of a consistant microporous layer,
- is delivered in roll,
- easy to handle and cut

PRODUCT DATA

Physical properties of FLEXILODICE

	FLEXILODICE 1,5 mm	**FLEXILODICE 2 mm**
Nominal thickness	1,5 mm	2 mm
Activation temperature	190°C	190°C
Free expansion ratio (at 550°C)	11 x initial thickness	11 x initial thicknes
Expansion pressure (at 300°C)	0,48 N/mm²	0,48 N/mm²
Weight per unit area	2,32 kg/m²	3,10 kg/m²
Shore A hardness (ISO 868)	80 shore	80 shore

Average values measured by the independant testing laboratory IBMB MPA Braunschweig (Germany)

TYPICAL APPLICATIONS :

The intumescent fire seal FLEXILODICE is used in the following inside and outside applications :

- seals in perimeter of fire resistant systems (doors, shutters, dampers, cabinets, safes walls, penetrating cables, etc).
- fire resistance improvement of various building elements, etc.

RANGE OF PRODUCTS

Color : black (colored in the mass of intumescent seal).

Widths, thicknesses and lengths available:

FLEXILODICE 1,5 mm	FLEXILODICE 2 mm
9,5 x 1,5mm x roll of 140 lm	10 x 2 mm x roll of 100 lm
15 x 1,5 mm x roll of 140 lm	15 x 2 mm x roll of 100 lm
	18 x 2 mm x roll of 100 lm
	20 x 2 mm x roll of 100 lm
	25 x 2 mm x roll of 100 lm
	30 x 2 mm x roll of 100 lm
	33 x 2 mm x roll of 100 lm
	37 x 2 mm x roll of 100 lm
	40 x 2 mm x roll of 100 lm
	50 x 2 mm x roll of 100 lm

Other thicknesses and widths can also be produced on request.

Self-adhesive backing (ref. SA) :

FLEXILODICE can receive a self-adhesive backing in order to ease the installation.

TOLERANCES

Thickness FLEXILODICE (*)	+ 0,2 mm / - 0,3 mm
Width	+ 0,2 mm / - 0,5 mm

(*) tolerances measured on FLEXILODICE without self adhesive backing.

FITTING INSTRUCTIONS

The intumescent seal FLEXILODICE developing an average expansion pressure, it is advised to fit him, in case of sealing for a fire rated door, on the edge of the door leaf or the frame.

In order to obtain an aesthetical installation, FLEXILODICE will be fitted in a groove of the same width as the section. This groove will also allow to control the expansion of the intumescent material.

The surface must be free from dust, fat and wax-type materials. Remove badly adhering coatings. Check the compatibility of the self-adhesive backing with the existing coating.

Fixation can be done by glueing but we highly recommend an installation with a self-adhesive backing really esay to use odice

FLEXILODICE

Flexible intumescent seal

New Pro

Technical data sheet

Packaging

The intumescent fire seals FLEXILODICE are delivered in roll and packed in card boxes.

Storage

Stock in a dry and well-ventilated area.

Safety and hygiene measures

Observe the ordinary working hygiene.
Refer to the Material and Safety data sheet of FLEXILODICE.

IMPORTANT: while the descriptions, designs, data and information contained herein are presented in
and believed to be accurate, it is provided for your guidance only. Because many factors may affect
or application/use, we recommend that you make tests to determine the suitability of a product for yo
particular purpose prior to use. No warranties of any kind, either express or implied, including warran
merchantability or fitness for a particular purpose, are made regarding products described or design
information set forth, or that the products, designs, data or information may be used without infringin
intellectual property rights of others. In no case shall the descriptions, information, data or designs
considered a part of our terms and conditions of sale. Further, you expressly understand and agree
descriptions, designs, data and information furnished by ODICE hereunder are given free of charge a
assumes no obligation or liability for the description, designs, data and information given or results
such being given and accepted at your risk.

ODICE S.A. Fire Protection
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Reference: technical data sheet FLEXILODICE thickness = 1,5 mm & 2 mm Rev.1
Updated : 07/2005

Appendix3 Ideal gas specific heats various gases (continued)

TABLE A–2

Ideal-gas specific heats of various common gases (*Concluded*)

(c) As a function of temperature

$$\bar{c}_p = a + bT + cT^2 + dT^3$$

$$(T \text{ in K}, \bar{c}_p \text{ in kJ/kmol} \cdot \text{K})$$

Substance	Formula	a	b	c	d	Temperature range, K	% error Max.	% error Avg.
Nitrogen	N_2	28.90	-0.1571×10^{-2}	0.8081×10^{-5}	-2.873×10^{-9}	273–1800	0.59	0.34
Oxygen	O_2	25.48	1.520×10^{-2}	-0.7155×10^{-5}	1.312×10^{-9}	273–1800	1.19	0.28
Air	—	28.11	0.1967×10^{-2}	0.4802×10^{-5}	-1.966×10^{-9}	273–1800	0.72	0.33
Hydrogen	H_2	29.11	-0.1916×10^{-2}	0.4003×10^{-5}	-0.8704×10^{-9}	273–1800	1.01	0.26
Carbon monoxide	CO	28.16	0.1675×10^{-2}	0.5372×10^{-5}	-2.222×10^{-9}	273–1800	0.89	0.37
Carbon dioxide	CO_2	22.26	5.981×10^{-2}	-3.501×10^{-5}	7.469×10^{-9}	273–1800	0.67	0.22
Water vapor	H_2O	32.24	0.1923×10^{-2}	1.055×10^{-5}	-3.595×10^{-9}	273–1800	0.53	0.24
Nitric oxide	NO	29.34	-0.09395×10^{-2}	0.9747×10^{-5}	-4.187×10^{-9}	273–1500	0.97	0.36
Nitrous oxide	N_2O	24.11	5.8632×10^{-2}	-3.562×10^{-5}	10.58×10^{-9}	273–1500	0.59	0.26
Nitrogen dioxide	NO_2	22.9	5.715×10^{-2}	-3.52×10^{-5}	7.87×10^{-9}	273–1500	0.46	0.18
Ammonia	NH_3	27.568	2.5630×10^{-2}	0.99072×10^{-5}	-6.6909×10^{-9}	273–1500	0.91	0.36
Sulfur	S_2	27.21	2.218×10^{-2}	-1.628×10^{-5}	3.986×10^{-9}	273–1800	0.99	0.38
Sulfur dioxide	SO_2	25.78	5.795×10^{-2}	-3.812×10^{-5}	8.612×10^{-9}	273–1800	0.45	0.24
Sulfur trioxide	SO_3	16.40	14.58×10^{-2}	-11.20×10^{-5}	32.42×10^{-9}	273–1300	0.29	0.13
Acetylene	C_2H_2	21.8	9.2143×10^{-2}	-6.527×10^{-5}	18.21×10^{-9}	273–1500	1.46	0.59
Benzene	C_6H_6	−36.22	48.475×10^{-2}	-31.57×10^{-5}	77.62×10^{-9}	273–1500	0.34	0.20
Methanol	CH_4O	19.0	9.152×10^{-2}	-1.22×10^{-5}	-8.039×10^{-9}	273–1000	0.18	0.08
Ethanol	C_2H_6O	19.9	20.96×10^{-2}	-10.38×10^{-5}	20.05×10^{-9}	273–1500	0.40	0.22
Hydrogen chloride	HCl	30.33	-0.7620×10^{-2}	1.327×10^{-5}	-4.338×10^{-9}	273–1500	0.22	0.08
Methane	CH_4	19.89	5.024×10^{-2}	1.269×10^{-5}	-11.01×10^{-9}	273–1500	1.33	0.57
Ethane	C_2H_6	6.900	17.27×10^{-2}	-6.406×10^{-5}	7.285×10^{-9}	273–1500	0.83	0.28
Propane	C_3H_8	−4.04	30.48×10^{-2}	-15.72×10^{-5}	31.74×10^{-9}	273–1500	0.40	0.12
n-Butane	C_4H_{10}	3.96	37.15×10^{-2}	-18.34×10^{-5}	35.00×10^{-9}	273–1500	0.54	0.24
i-Butane	C_4H_{10}	−7.913	41.60×10^{-2}	-23.01×10^{-5}	49.91×10^{-9}	273–1500	0.25	0.13
n-Pentane	C_5H_{12}	6.774	45.43×10^{-2}	-22.46×10^{-5}	42.29×10^{-9}	273–1500	0.56	0.21
n-Hexane	C_6H_{14}	6.938	55.22×10^{-2}	-28.65×10^{-5}	57.69×10^{-9}	273–1500	0.72	0.20
Ethylene	C_2H_4	3.95	15.64×10^{-2}	-8.344×10^{-5}	17.67×10^{-9}	273–1500	0.54	0.13
Propylene	C_3H_6	3.15	23.83×10^{-2}	-12.18×10^{-5}	24.62×10^{-9}	273–1500	0.73	0.17

Source: B. G. Kyle, *Chemical and Process Thermodynamics* (Englewood Cliffs, NJ: Prentice-Hall, 1984). Used with permission.

Ideal-gas specific heats of various common gases (Continued)

(b) At various temperatures

Temperature, K	c_p kJ/kg · K	c_v kJ/kg · K	k	c_p kJ/kg · K	c_v kJ/kg · K	k	c_p kJ/kg · K	c_v kJ/kg · K	k
	Air			Carbon dioxide, CO_2			Carbon monoxide, CO		
250	1.003	0.716	1.401	0.791	0.602	1.314	1.039	0.743	1.400
300	1.005	0.718	1.400	0.846	0.657	1.288	1.040	0.744	1.399
350	1.008	0.721	1.398	0.895	0.706	1.268	1.043	0.746	1.398
400	1.013	0.726	1.395	0.939	0.750	1.252	1.047	0.751	1.395
450	1.020	0.733	1.391	0.978	0.790	1.239	1.054	0.757	1.392
500	1.029	0.742	1.387	1.014	0.825	1.229	1.063	0.767	1.387
550	1.040	0.753	1.381	1.046	0.857	1.220	1.075	0.778	1.382
600	1.051	0.764	1.376	1.075	0.886	1.213	1.087	0.790	1.376
650	1.063	0.776	1.370	1.102	0.913	1.207	1.100	0.803	1.370
700	1.075	0.788	1.364	1.126	0.937	1.202	1.113	0.816	1.364
750	1.087	0.800	1.359	1.148	0.959	1.197	1.126	0.829	1.358
800	1.099	0.812	1.354	1.169	0.980	1.193	1.139	0.842	1.353
900	1.121	0.834	1.344	1.204	1.015	1.186	1.163	0.866	1.343
1000	1.142	0.855	1.336	1.234	1.045	1.181	1.185	0.888	1.335
	Hydrogen, H_2			Nitrogen, N_2			Oxygen, O_2		
250	14.051	9.927	1.416	1.039	0.742	1.400	0.913	0.653	1.398
300	14.307	10.183	1.405	1.039	0.743	1.400	0.918	0.658	1.395
350	14.427	10.302	1.400	1.041	0.744	1.399	0.928	0.668	1.389
400	14.476	10.352	1.398	1.044	0.747	1.397	0.941	0.681	1.382
450	14.501	10.377	1.398	1.049	0.752	1.395	0.956	0.696	1.373
500	14.513	10.389	1.397	1.056	0.759	1.391	0.972	0.712	1.365
550	14.530	10.405	1.396	1.065	0.768	1.387	0.988	0.728	1.358
600	14.546	10.422	1.396	1.075	0.778	1.382	1.003	0.743	1.350
650	14.571	10.447	1.395	1.086	0.789	1.376	1.017	0.758	1.343
700	14.604	10.480	1.394	1.098	0.801	1.371	1.031	0.771	1.337
750	14.645	10.521	1.392	1.110	0.813	1.365	1.043	0.783	1.332
800	14.695	10.570	1.390	1.121	0.825	1.360	1.054	0.794	1.327
900	14.822	10.698	1.385	1.145	0.849	1.349	1.074	0.814	1.319
1000	14.983	10.859	1.380	1.167	0.870	1.341	1.090	0.830	1.313

Source: Kenneth Wark, Thermodynamics, 4th ed. (New York: McGraw-Hill, 1983), p. 783, Table A-4M. Originally published in Tables of Thermal Properties of Gases, NBS Circular 564, 1955.

Appendix4 Same properties of air

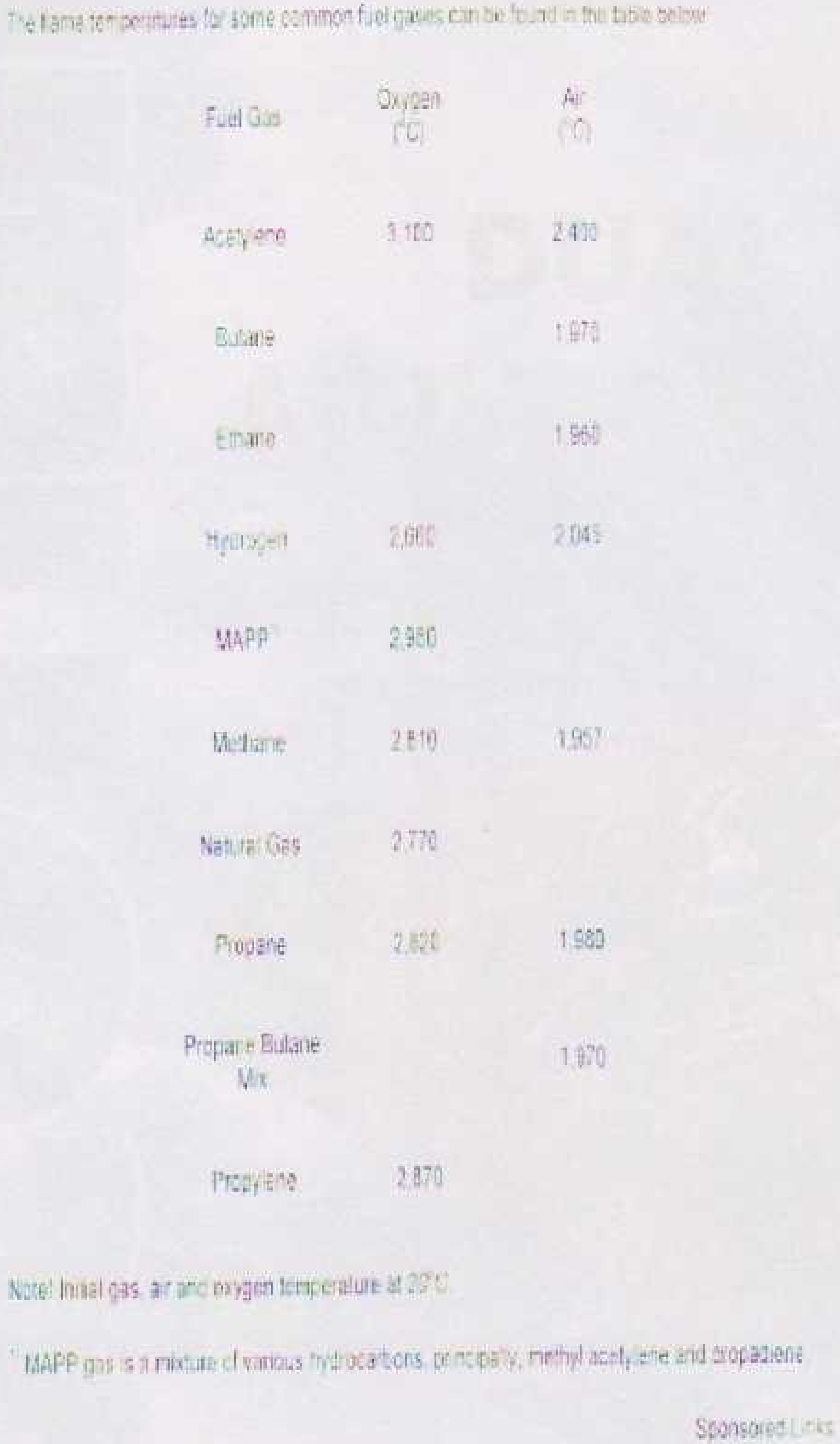
Properties of air at atmospheric pressure†

The values of μ, k, c_p, and Pr are not strongly pressure-dependent and may be used over a fairly wide range of pressures

T, K	ρ kg/m³	c_p kJ/kg · °C	$\mu \times 10^5$ kg/m · s	$\nu \times 10^6$ m²/s	k W/m · °C	$\alpha \times 10^4$ m²/s	Pr
100	3.6010	1.0266	0.6924	1.923	0.009246	0.02501	0.770
150	2.3675	1.0099	1.0283	4.343	0.013735	0.05745	0.753
200	1.7684	1.0061	1.3289	7.490	0.01809	0.10165	0.739
250	1.4128	1.0053	1.5990	11.31	0.02227	0.15675	0.722
300	1.1774	1.0057	1.8462	15.69	0.02624	0.22160	0.708
350	0.9980	1.0090	2.075	20.76	0.03003	0.2983	0.697
400	0.8826	1.0140	2.286	25.90	0.03365	0.3760	0.689
450	0.7833	1.0207	2.484	31.71	0.03707	0.4222	0.683
500	0.7048	1.0295	2.671	37.90	0.04038	0.5564	0.680
550	0.6423	1.0392	2.848	44.34	0.04360	0.6532	0.680
600	0.5879	1.0551	3.018	51.34	0.04659	0.7512	0.680
650	0.5430	1.0635	3.177	58.51	0.04953	0.8578	0.682
700	0.5030	1.0752	3.332	66.25	0.05230	0.9672	0.684
750	0.4709	1.0856	3.481	73.91	0.05509	1.0774	0.686
800	0.4405	1.0978	3.625	82.29	0.05779	1.1951	0.689
850	0.4149	1.1095	3.765	90.75	0.06028	1.3097	0.692
900	0.3925	1.1212	3.899	99.3	0.06279	1.4271	0.696
950	0.3716	1.1321	4.023	108.2	0.06525	1.5510	0.699
1000	0.3524	1.1417	4.152	117.8	0.06752	1.6779	0.702
1100	0.3204	1.160	4.44	138.6	0.0732	1.969	0.704
1200	0.2947	1.179	4.69	159.1	0.0782	2.251	0.707
1300	0.2707	1.197	4.93	182.1	0.0837	2.583	0.705
1400	0.2515	1.214	5.17	205.5	0.0891	2.920	0.705
1500	0.2355	1.230	5.40	229.1	0.0946	3.262	0.705
1600	0.2211	1.248	5.63	254.5	0.100	3.609	0.705
1700	0.2082	1.267	5.85	280.5	0.105	3.977	0.705
1800	0.1970	1.287	6.07	308.1	0.111	4.379	0.704
1900	0.1858	1.309	6.29	338.5	0.117	4.811	0.704
2000	0.1762	1.338	6.50	369.0	0.124	5.260	0.702
2100	0.1682	1.372	6.72	399.6	0.131	5.715	0.700
2200	0.1602	1.419	6.93	432.6	0.139	6.120	0.707
2300	0.1538	1.482	7.14	464.0	0.149	6.540	0.710
2400	0.1458	1.574	7.35	504.0	0.161	7.020	0.718
2500	0.1394	1.688	7.57	543.5	0.175	7.441	0.730

†From Natl. Bur. Stand. (U.S.) Circ. 564, 1955.

Appendix5 Gas flam temperature



The flame temperatures for some common fuel gases can be found in the table below

Fuel Gas	Oxygen (°C)	Air (°C)
Acetylene	3,100	2,400
Butane		1,970
Ethane		1,960
Hydrogen	2,660	2,045
MAPP[1]	2,980	
Methane	2,810	1,957
Natural Gas	2,770	
Propane	2,820	1,980
Propane Butane Mix		1,970
Propylene	2,870	

Note! Initial gas, air and oxygen temperature at 20°C

[1] MAPP gas is a mixture of various hydrocarbons, principally, methyl acetylene and propadiene

Ecoflam

DUAL MULTICALOR

MONOBLOCK 23 - 17000 kW

DUOBLOCK 180 - 25000 kW

DUAL FUEL BURNERS
КОМБИНИРОВАННЫЕ ГОРЕЛКИ
BRULEURS MIXTE
QUEMADORES MIXTOS

• EN • RU • FR • ES

OPERATION / МОДИФИКАЦИИ

...	• On-Off	• одноступенчатая горелка
P...	• On-Off Soft Star	• одноступенчатая горелка (с плавным пуском)
P...AB	• HI-LOW with servomotor	• двухступенчатая горелка с электроприводом воздушной заслонки
P...PR	• Progressive	• с плавным переходом с малого на большое горение
P...MD	• Modulating	• с модуляцией мощности
TS	• Separate head	• горелка с отдельностоящим дутьевым вентилятором (блочная)

MAIN FEATURES / ХАРАКТЕРИСТИКИ

- Aluminium casing up to Multicalor 200.1 and steel casing from 300.1 with electrical panel integrated on the burner.
- Adjustable combustion head for fine tuning / matching with different shapes of combustion chamber.
- Gas pilot from Multicalor 170.1.
- Hi - Low version with electric servomotor and integrated system for the regulation of air gas and light oil with two nozzle from Multicalor 45 to Multicalor 300.1.
- Progressive version with electrical servomotor and double adjustable mechanical cam that allows air gas/light oil fine tuning.
- Modulating version with PID system controller with digital set point display and real time value.
- Progressive or modulating nozzle with flow and return. Shut down flow system on the nozzle managed by coil from Multicalor 700.1.
- Firing head with adjustable primary air system that changes according to output required.
- Easy maintenance with sliding bars system. Standard from Multicalor 700.1 and on request from Multicalor 300.1.
- Standard version running on manual fuel selection mode and on request automatic fuel changeover. The automatic change over system can be triggered by gas pressure or by a timer.
- Special version for all type of applications and fuel charachteristics on request.
- Duoblock range 180 - 25000 kW.

Duol 4 P

- Алюминиевый корпус для моделей вплоть до Multicalor 200.1 и стальной, начиная с модели 300.1, со встроенной панелью управления.
- Регулируемая огневая головка, предназначенная для работы с двумя типами топлива, упрощает наладку горелки для работы в сочетании с различными камерами сгорания.
- Газовый запальник (метан или сжиженный газ), начиная с модели Multicalor 170.1.
- Двухступенчатые горелки с электроприводом воздушной заслонки и интегрированной системой регулировки расхода воздуха, газа и дизельного топлива, с двумя форсунками, в моделях с Multicalor 45 до Multicalor 300.1 .
- Новая система пропорционального регулирования расхода воздуха, газа и дизтоплива с двумя регулировочными лекалами изменяемой геометрии для моделей PR (с плавным переходом с малого на большое горение) и MD (с модуляцией мощности).
- Модели с модуляцией мощности оборудуются PID-регулятором с цифровым дисплеем, на котором отображаются фактические значения параметров и который позволяет изменять значения уставок.
- Начиная с модели Multicalor 700.1, в исполнении PR и MD, реализован контур циркуляции топлива в огневой головке (дополнительный электромагнитный клапан перекрывает подачу топлива непосредственно у форсунок).
- Автоматическая система регулировки расхода первичного воздуха в зависимости от требуемой мощности, начиная с модели Multicalor 700.1.
- Простота в обслуживании – доступ к огневой головке без снятия горелки с котла.
- Стандартная модель с ручным переключением ступеней мощности. С автоматическим переключением - по отдельному заказу. Коммутирующая автоматическая аппаратура работает по давлению газа либо по команде таймера.
- Все горелки отличаются универсальностью и могут использоваться как на гражданских, так и промышленных объектах.

Multicalor 100.1 P AB

NCTIONNEMENT / *FUNCIONAMIENTO*

	• 1ère ALLURE	• *1a LLAMA*
L	• 1ère ALLURE démarrage réduit	• *Salto de presion*
LAB	• Deux allures	• *Baja/Alta LLAMA con aire motorizado*
LPR	• Deux allures progressives	• *Progresivo*
LMD	• Modulant	• *Modulante*
S	• Tête séparée	• *Cabeza separada*

ARACTERISTIQUES / *CARACTERISTICAS*

Corps en aluminium jusqu'au Multicalor 200.1, corps en acier à partir du 300.1; avec tableau de bord integré au brûleur.

Tête de combustion pour deux combustibles réglable pour garantir de meilleurs accouplements sur différentes chambres de combustion.

Pilote de gaz (gaz naturel et gpl), à partir du Multicalor 170.1.

Versions 2 allures avec servomoteur et système integré pour le réglage de l'air, du gaz et du fioul; avec 2 gicleurs à partir du Multicalor 45 jusqu'au 300.1.

Nouveau système de réglage proportionnel air, gaz et fuel avec double came à profils variables, pour les versions progressives PR et modulantes MD.

Versions modulantes avec thermorégulateur PID et affichage numérique qui donne la valeur réelle et permet de régler le point de consigne(LMV 51/52 en option).

Gicleur à retour pour versions PR et MD avec système de fermeture électromagnétique du gicleur à partir du Multicalor 700.1.

Système de réglage de l'air primaire en fonction du débit demandé.

Facilité d'entretien grâce à la possibilité d'extraire la tête de combustion par l'arriere du brûleur.

Versions standard à commutation manuelle et, sur demande, automatique. Le système de commutation automatique peut être commandé par la pression du gaz ou d'un autre signal.

Version spéciale sur demande, pour toutes applications ou autres combustibles.

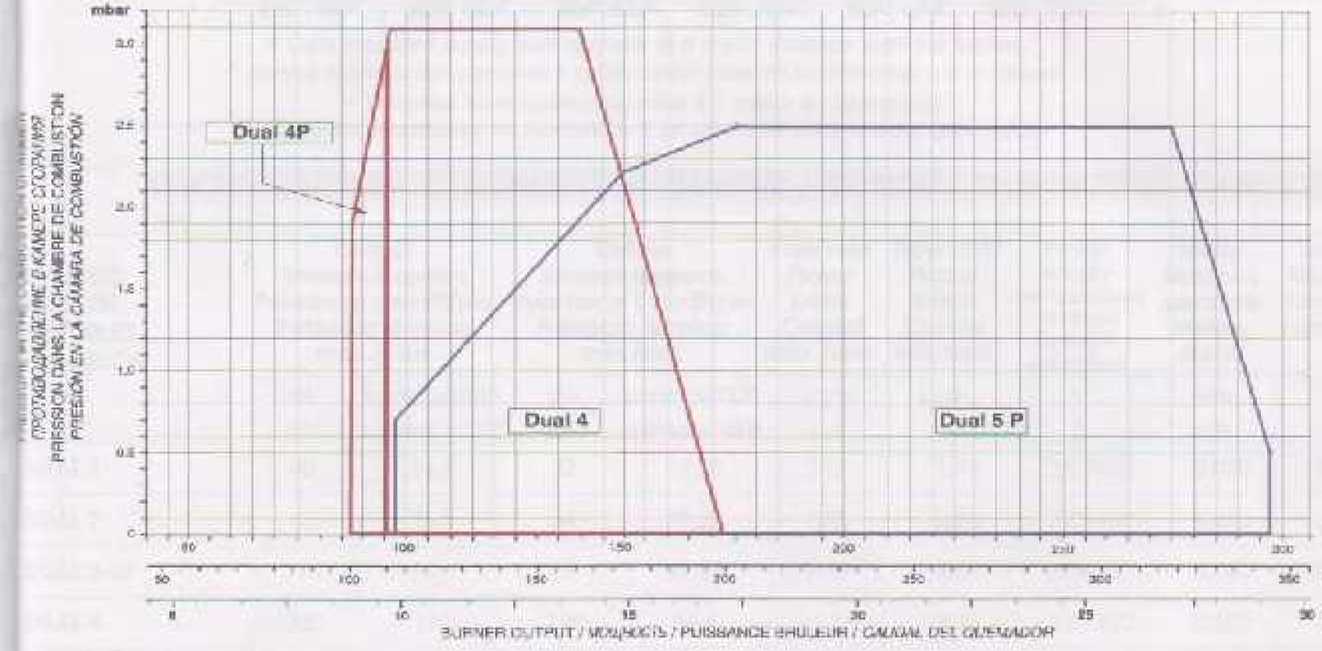
Gamme Duoblock 180 - 25000 kW.

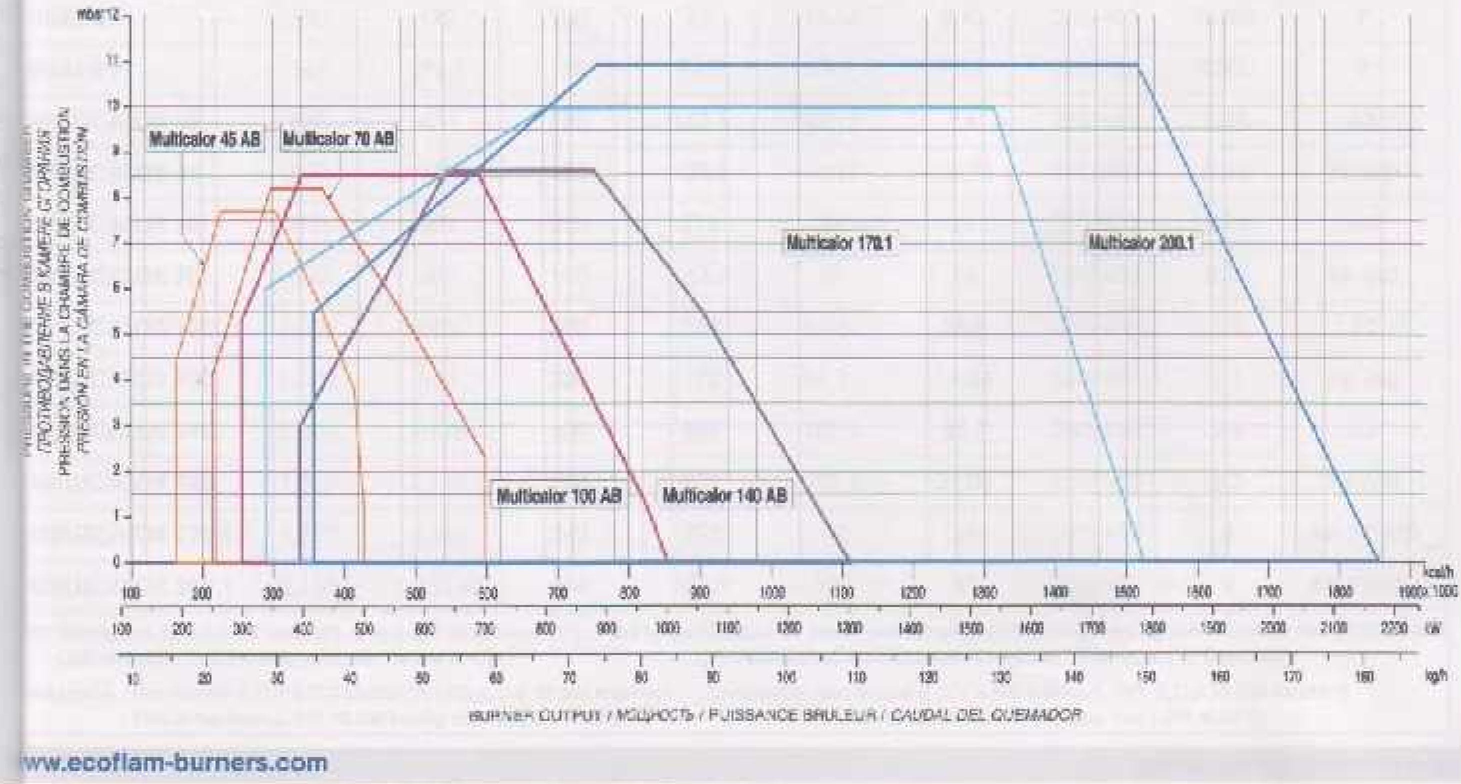
Multicalor 800.1 DUO PR/PR

MULTICALOR 1000.1 MD/MD

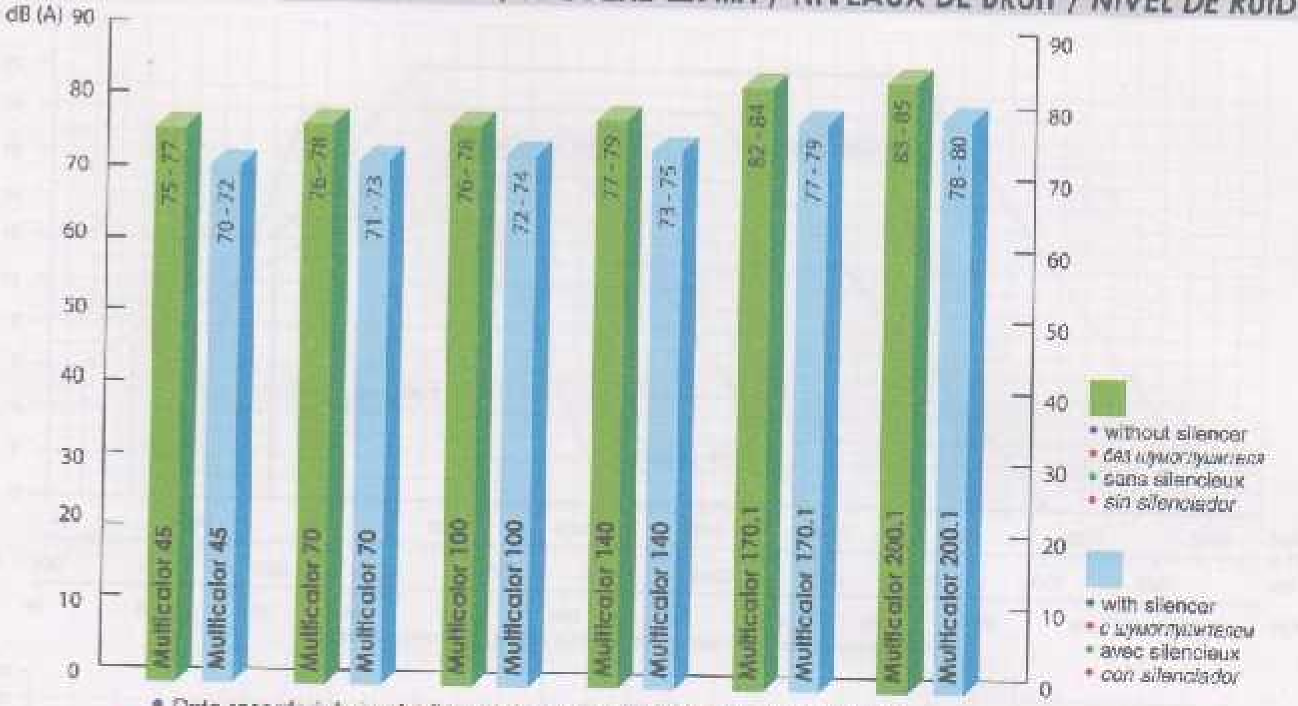
- *Cuerpo de aleación de aluminio hasta el modelo Multicalor 200.1 y en fundición de acero a partir del modelo 300.1, con el cuadro eléctrico incorporado en el quemador.*
- *Cabeza de combustión regulable para garantizar el mejor acoplamiento en las diferentes cámaras de combustión.*
- *Piloto de gas (metano o GLP) desde el Multicalor 170.1.*
- *Versión de dos llamas con servomotor y sistema integrado para la regulación del aire/gas o gasóleo, con dos inyectores desde el Multicalor 45 al 300.1.*
- *Nuevo sistema de regulación proporcional aire gas y gasóleo con doble cama a perfil variable, para la versión PR y MD.*
- *Versión modulante con termoregulador PID con display digital que visualiza el valor real y permite la regulación del set point.*
- *Inyector a reflujo para las versiones PR y MD con sistema de cierre del flujo al inyector mediante la bobina, para el Multicalor 700.1.*
- *Sistema de regulación del aire primario que varia en base a la potencia requerida.*
- *Fácil mantenimiento gracias a la fácil extracción de la cabeza de combustión del cuerpo del quemador.*
- *Versión estándar con conmutación manual y a petición se puede fabricar con conmutación automática. El sistema de conmutación automatico puede ser controlado por la presión del gas o por un temporizador.*
- *Versión a petición del cliente para cualquier tipo de instalacion industrial y características de combustible.*
- *Gama duoblock 180 - 25000 kW.*

WORKING FIELDS / *РАБОЧИЙ ДИАПАЗОН* / COURBES DE TRAVAIL / *CURVAS DE TRABAJO*





NOISE LEVEL / *УРОВЕНЬ ШУМА* / NIVEAUX DE BRUIT / *NIVEL DE RUIDOS*



- Data recorded during testing made at a meter distance from the burner.
- *Данные получены при измерении в лабораторных условиях на расстоянии 1 м от горелки.*
- Données techniques mesurées à 1 mètre en laboratoire.
- *Medidas efectuadas en laboratorio a un metro de distancia del quemador.*

TECHNICAL DATA / *ТЕХНИЧЕСКИЕ ДАННЫЕ* / DONNEES TECHNIQUES / *DATOS TECNICOS*

MODELS МОДЕЛИ MODELES MODELOS	Output *Тепловая мощность* Puissance calorifique *Potencia térmica* max./*макс.*		Output *Тепловая мощность* Puissance calorifique *Potencia térmica* min./*мин.*		Flow rate *Расход* Débit *Caudal* max./*макс.*	Flow rate *Расход* Débit *Caudal* min./*мин.*	Power supply *Электропитание* Tension *Tensión eléctrica*	Motor *Мощность двигателя* Moteur *Motor*	Operation *Модификация* Fonctionnement *Funcionamiento*
	kW *кВт*	kcal/hx1000 *ккал/час x 1000*	kW *кВт*	kcal/hx1000 *ккал/час x 1000*	kg/h *кг/ч*	kg/h *кг/ч*	V *В*	kW *кВт*	
DUAL 1	40	34,4	23	19.78	3,37	1.94	230/400	0,050	ON-OFF
DUAL 2	65	55,9	34	29,24	5.48	2.86	230/400	0,050	ON-OFF
DUAL 3-3P	110	94,6	58	49.88	9,27	4,89	230/400	0,200	ON-OFF / P
DUAL 4	200	172	110	94,6	16.86	9,27	230/400	0.250	ON-OFF
DUAL 4 P	200	172	100	86	16.86	8,43	230/400	0,250	P
DUAL 5 P	345	296,7	110	94,6	29.1	9.27	230/400	0,300	P
MULTICALOR 45	500	430	190	163,4	42,17	16	230/400	0,55	AB
MULTICALOR 45	500	430	120	103,2	42,17	10,12	230/400	0.55	PR-MD
MULTICALOR 70	700	602	250	215	59	21	230/400	0,74	AB
MULTICALOR 70	700	602	190	163,4	59	16	230/400	0,74	PR-MD
MULTICALOR 100	1.000	860	300	258	84,31	25,3	230/400	1,1	AB
MULTICALOR 100	1.000	860	200	172	84,31	16.86	230/400	1,1	PR-MD
MULTICALOR 140	1.300	1.118	400	344	109,6	33,7	230/400	2,2	AB
MULTICALOR 140	1.300	1.118	250	215	109,6	21.08	230/400	2,2	PR-MD
MULTICALOR 170.1	1.770	1.526	342	295	150	29	230/400	3	AB-PR-MD
MULTICALOR 200.1	2.150	1.853,45	414	356.9	182	35	230/400	4	AB-PR-MD

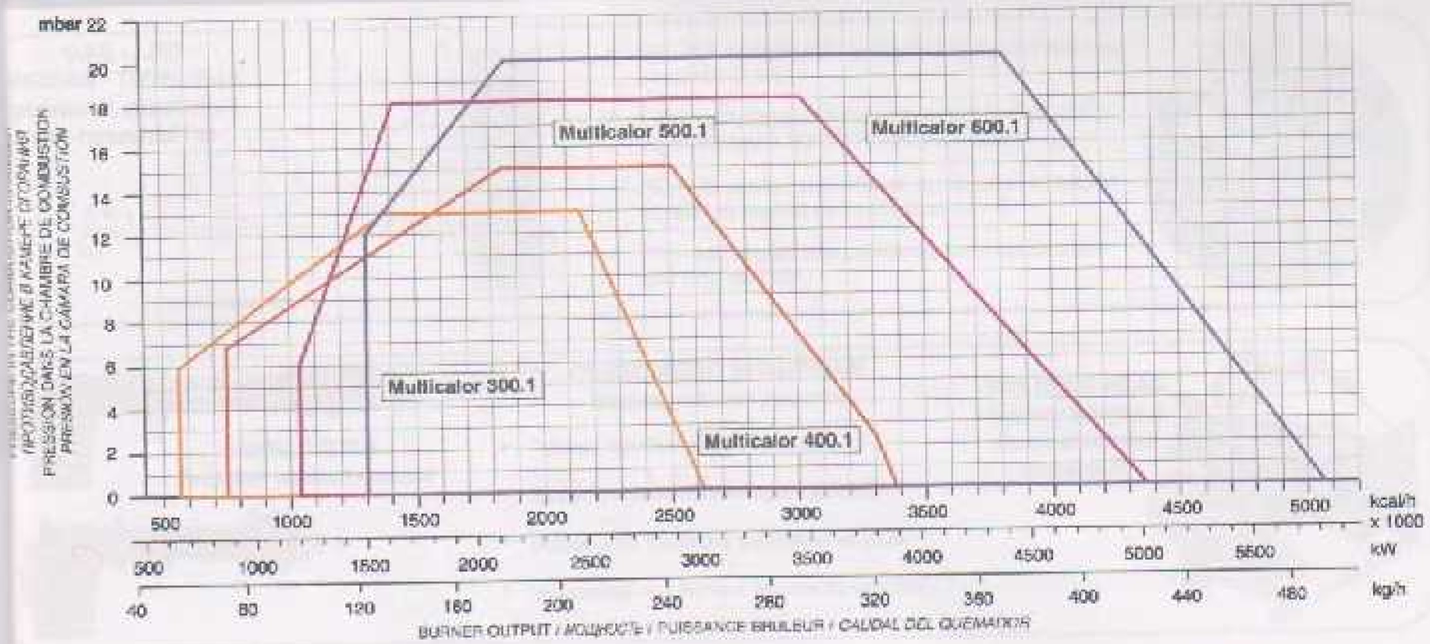
el: Natural Gas (L.C.V. 8.570 kcal/Nm³), LPG (L.C.V. 22.260 kcal/Nm³)
: Light oil (L.C.V. 10.200 kcal/kg max. visc 1,5°E at 20°C)

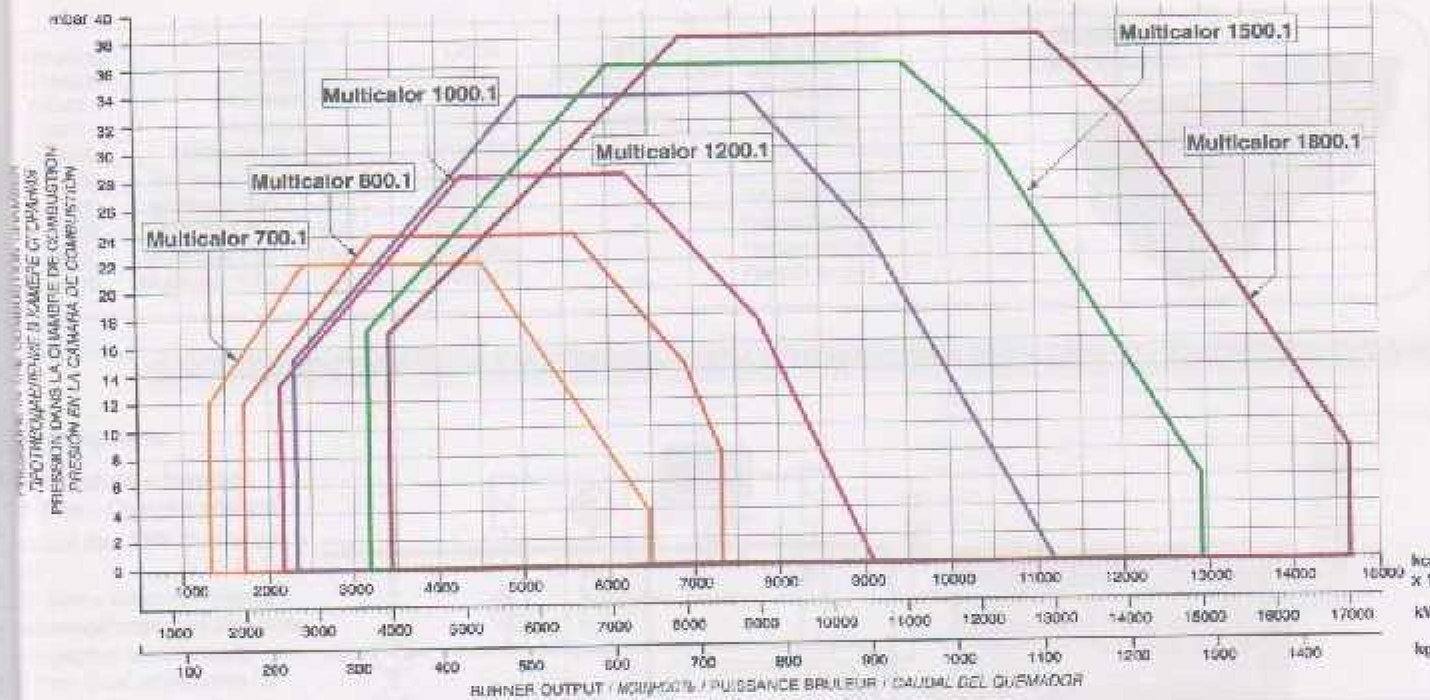
Вид топлива: Природный газ (низшая теплота сгорания 8.570 ккал/Нм3), сжиж. газ (низшая теплота сгорания 22.260ккал/Нм3)
Дизтопливо(низшая теплота сгорания 10.200 ккал/кг. Макс. вязкость 1,5°E при 20°C)

ombustible : Gaz Naturel (L.C.V. 8.570 kcal/Nm3), LPG (L.C.V. 22.260 kcal/Nm³)
: Fuel domestique (L.C.V. 10.200 kcal/kg max. visc 1,5°E at 20°C)

Combustible: Gas Natural (L.C.V. 8.570 kcal/Nm³), GPL (L.C.V. 22.260 kcal/Nm³)
: Gasóleo (L.C.V. 10.200 kcal/kg max. visc 1,5°E at 20°C)

WORKING FIELDS / *РАБОЧИЙ ДИАПАЗОН* / COURBES DE TRAVAIL / *CURVAS DE TRABAJO*





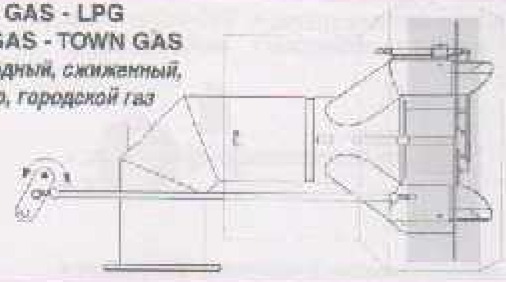
TECHNICAL DATA / *ТЕХНИЧЕСКИЕ ДАННЫЕ* / DONNEES TECHNIQUES / *DATOS TECNICOS*

MODELS **МОДЕЛИ** **MODELES** **MODELOS**	Output *Тепловая мощность* Puissance calorifique *Potencia térmica* max./*макс.*		Output *Тепловая мощность* Puissance calorifique *Potencia térmica* min./*мин.*		Flow rate *Расход* Débit Caudal max./*макс.*	Flow rate *Расход* Débit Caudal min./*мин.*	Power supply *Электропитание* Tension *Tensión eléctrica*	Motor *Мощность двигателя* Moteur *Motor*	Operation *Модификация* Fonctionnement *Funcionamiento*
	kW *кВт*	kcal/hx1000 *ккал/час x 1000*	kW *кВт*	kcal/hx1000 *ккал/час x 1000*	kg/h *кг/ч*	kg/h *кг/ч*	V *В*	kW *кВт*	
MULTICALOR 300.1	3.000	2.586	630	543.1	253	53	230/400	5,5	**AB-PR-MD**
MULTICALOR 400.1	3.900	3.362	875	754.3	330	74	230/400	7.5	**PR-MD**
MULTICALOR 500.1	5.000	4.310	1.200	1.034.5	423	101	230/400	11	**PR-MD**
MULTICALOR 600.1	5.800	5.000	1.500	1.290	490	126	230/400	15	**PR-MD**
MULTICALOR 700.1	7.500	6.465	1.500	1.290	634	126	230/400	15	**PR-MD**
MULTICALOR 800.1	8.500	7.327.5	2.000	1.724	718	169	230/400	18,5	**PR-MD**
MULTICALOR 1000.1	10.500	9.052	2.500	2.155	887	211	230/400	22	**PR-MD**
MULTICALOR 1200.1	13.000	11.207	2.700	2.327.6	1099	228	230/400	37	**PR-MD**
MULTICALOR 1500.1	15.000	12.931	3.690	3.181	1.268	312	230/400	45	**PR-MD**
MULTICALOR 1800.1	17.000	14.655	4.000	3.448,27	1.437	338	230/400	55	**PR-MD**

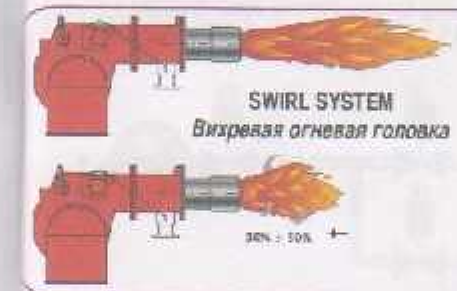
Fuel: Natural Gas (L.C.V. 8.570 kcal/Nm³), LPG (L.C.V. 22.260 kcal/Nm³)
: Light oil (L.C.V. 10.200 kcal/kg max. visc 1,5°E at 20°C)
Combustible : Gaz Naturel (L.C.V. 8.570 kcal/Nm3), LPG (L.C.V. 22.260 kcal/Nm³)
Fuel domestique (L.C.V. 10.200 kcal/kg max. visc 1,5°E at 20°C)

Вид топлива: Природный газ (низшая теплота сгорания 8.570 ккал/Нм3), сжиж. газ (низшая теплота сгорания 22.260 ккал/Нм3)
Дизтопливо(низшая теплота сгорания 10.200 ккал/кг. Макс. вязкость 1,5°E при 20°C)
Combustible: Gas Natural (L.C.V. 8.570 kcal/Nm³), GPL (L.C.V. 22.260 kcal/Nm³)
- Gasóleo (L.C.V. 10.200 kcal/kg max. visc 1,5°E at 20°C)

GAS - LPG
BIOGAS - TOWN GAS
природный, сжиженный, био, городской газ



- PR - MD version with mechanical movable head and turndown of 1:5.
- С РЕГУЛИРУЕМЫМ ПОЛОЖЕНИЕМ ОГНЕВОЙ ГОЛОВКИ (КОЭФФИЦИЕНТ РАБОЧЕГО РЕГУЛИРОВАНИЯ 1:5).
- PR - MD version avec tête de combustion à position variable et rapport de modulation de 1:5.
- *PR – MD versión con cabeza de combustion movil con ratio de 1 :5.*



SWIRL SYSTEM
Вихревая огневая головка

CUSTOMISED SOLUTIONS
Индивидуальные решения

- Tailored solution of flame shape.
- *Горелки с изменяемой геометрией факела.*
- Solusion de flamme a geometrie variable.
- *Soluciones con flama a geometría variable.*

MULTIPLE HEAD
Горелки с двумя и более огневыми головками.

Housing *Отливка* Volute *Fusion*	Models *МОДЕЛИ* Modeles *Modelos*	Code код Code *Código*	Option *доп. комплектация* Option *Opcional*	To be Included *ВКЛЮЧЕНО* À Ajouter *A incluyr*
FUS260	Multicalor 45 – 140	GRSIL260	•	-
FUS280	Multicalor 170.1 – 200.1	GRSIL280	•	-
FUS320	Multicalor 300.1 – 400.1	GRSIL320	•	Reccomended
FUS380	Multicalor 500.1 – 600.1	GRSIL380	•	Reccomended
FUS630	Multicalor 700.1 – 1200.1	GRSIL630	•	Reccomended
FUS710	Multicalor 1500.1 – 1800.1	GRSIL710	•	Reccomended

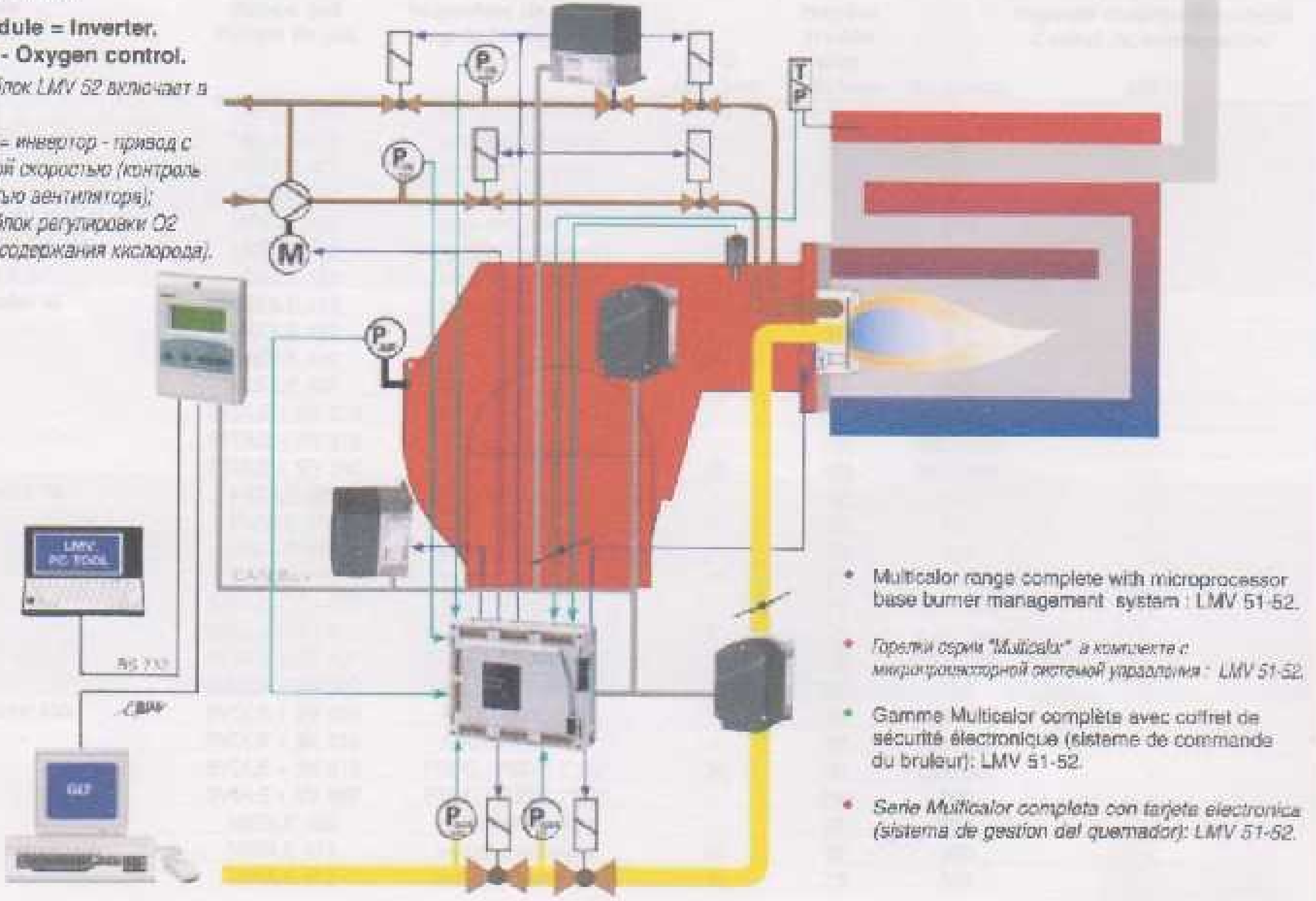
SILENCER
Шумоглушитель

MAX TURNDOWN WITH LMV 51 1÷6 / MAX TURNDOWN WITH LMV 52 AND INVERTER 1÷8

MV52 options:

SD module = Inverter.
2 Trim - Oxygen control.

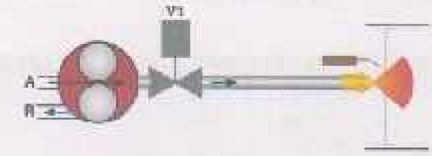
азовый блок LMV 52 включает в бя:
SD-блок = инвертор - привод с ременной скоростью (контроль скоростью вентилятора);
2 Trim - блок регулировки O2 онтроль содержания кислорода).



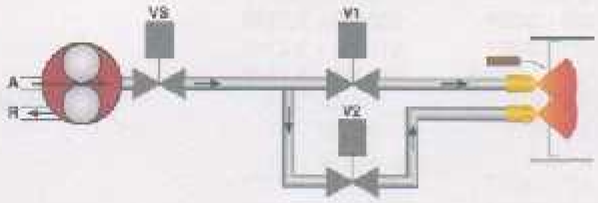
- Multicalor range complete with microprocessor base burner management system : LMV 51-52.
- *Горелки серии "Multicalor" в комплекте с микропроцессорной системой управления : LMV 51-52.*
- Gamme Multicalor complète avec coffret de sécurité électronique (sisteme de commande du bruleur): LMV 51-52.
- *Serie Multicalor completa con tarjeta electronica (sistema de gestion del quemador): LMV 51-52.*

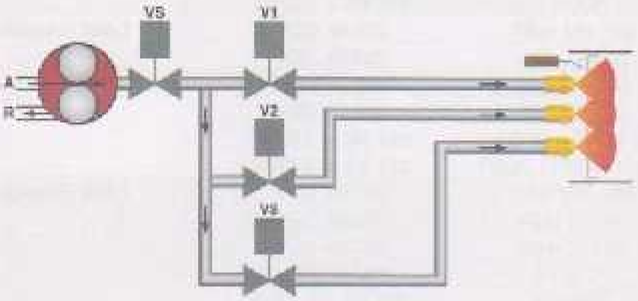
YDRAULIC CIRCUIT / *ГИДРАВЛИЧЕСКИЙ КОНТУР* / CIRCUIT HYDRAULIQUE / *SISTEMA HIDRAULICO*

- versions ON-OFF
- *одноступенчатая горелка*
- version 1 allure
- *quemador de 1 llama*



- versions with servomotor 2 nozzles (3 nozzles)
- *2х-ступенчатая горелка эл. приводом возд. заслонки (2 форсунки)*
- version deux allures avec 2 gicleurs(3 gicleurs)
- *quemador de 2 llamas con servomotor 2 inyectores (3 inyectores)*

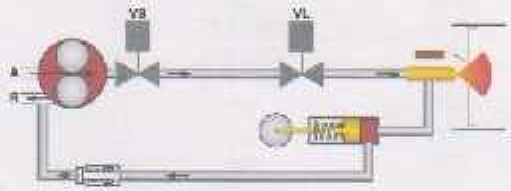


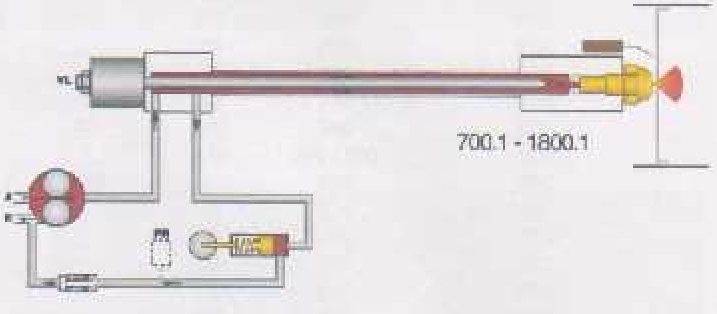


- versions with hydraulic pressure regulator (PR)
- *вариант с регулятором давления (PR)*
- versions avec régulateur de pression (PR)
- *version con regulador de presion (PR)*

45 - 200.1

300.1 - 600.1





700.1 - 1800.1

GAS TRAIN / *ГАЗОВЫЕ РАМПЫ* / RAMPE GAZ / *RAMPA DE GAS*

Models *Модели* **Modeles** **Modelos**	Gas train *Газовые рампы* Rampe gaz *Rampa de gas*	Gas governor & Filter *Стабилизатор давления* Régulateur de pression *Regulador de presión*	Pressure *Давление газа* Pression *Presión* *LPG* *min/мин.*	Gas *min/мин.*	*max/макс.*	Leakage control *Устройство контроля герметичности* Dispositif contrôle étanchéité *Control de estanqueidad* *EN676*
Dual 1	MBDLE 405	included-*включено*	15	17	360	-
Dual 2	MBDLE 405	included-*включено*	15	17	360	-
Dual 3	MBDLE 407	included-*включено*	15	17	360	-
Dual 4	MBDLE 407	included-*включено*	15	17	360	-
Dual 3 P	MBDLE 407	included-*включено*	15	17	360	-
Dual 4 P	MBDLE 410	included-*включено*	15	17	360	-
Dual 5 P	MBDLE 412	included-*включено*	15	17	360	-
Multicalor 45	MBDLE 415	included-*включено*	-	17	360	-
	MBDLE 412	included-*включено*	-	30	360	-
	MBDLE 410	included-*включено*	25	50	360	-
	MBDLE 407	included-*включено*	45	65	360	-
	SVDLE + SV 512	FSDC / FSDR 1"1/2"	-	20	200 / 500	-
	SVDLE + SV 512	FSDC / FSDR 1"	-	70	200 / 500	-
	SVDLE + SV 507	FSDC / FSDR 1"	45	120	200 / 500	-
Multicalor 70	MBDLE 420	included-*включено*	-	17	360	-
	MBDLE 415	included-*включено*	-	25	360	-
	MBDLE 412	included-*включено*	25	45	360	-
	MBDLE 410	included-*включено*	40	75	360	-
	SVDLE + SV 520	FSDC / FSDR 2"	-	15	200 / 500	-
	SVDLE + SV 512	FSDC / FSDR 1"1/2"	15	35	200 / 500	-
	SVDLE + SV 507	FSDC / FSDR 1"1/2"	-	140	200 / 500	-
	SVDLE + SV 507	FSDC / FSDR 1"	-	230	500	-
Multicalor 100	SVDLE + SV 520	FSDC / FSDR 2"	-	25	200 / 500	-
	SVDLE + SV 512	FSDC / FSDR 2"	-	50	200 / 500	-
	SVDLE + SV 512	FSDC / FSDR 1"1/2"	30	60	200 / 500	-
	SVDLE + SV 507	FSDC / FSDR 1"1/2"	-	280	500	-
	MBDLE 420	included-*включено*	-	27	360	-
	MBDLE 415	included-*включено*	25	35	360	-
	MBDLE 412	included-*включено*	40	75	360	-

GAS TRAIN / *ГАЗОВЫЕ РАМПЫ* / RAMPE GAZ / *RAMPA DE GAS*

Models *Модели* **Modeles** *Modelos*	Gas train *Газовыя рампы* Rampe gaz *Rampa de gas*	Gas governor & Filter *Стабилизатор давления* Régulateur de pression *Regulador de presión*	Pressure *Давление газа* Pression *Presión*			Leakage control *Устройство контроля герметичности* Dispositif contrôle étanchéité *Control de estanqueidad*
			LPG min/*мин.*	Gas min/*мин.*	max/*макс.*	*EN676*
Multicalor 140	VGD 20.503	Filter 2"	-	25	600	-
	SVDLE + SV 520	FSDC / FSDR 2"	-	40	200 / 500	-
	SVDLE + SV 512	FSDC / FSDR 2"	-	75	200 / 500	-
	SVDLE + SV 512	FSDC / FSDR 1"1/2"	40	100	200 / 500	-
	MBDLE 420	included-*включено*		40	360	-
	MBDLE 415	included-*включено*	30	50	360	-
	MBDLE 412	included-*включено*	50	100	360	-
Multicalor 170.1	VGD 40.080	Filter DN 80	-	20	700	VPS
	VGD 40.065	Filter DN 65	-	30	700	VPS
	VGD 20.503	Filter 2"	-	45	500	VPS
	SVDLE + SV 520	FSDC / FSDR 2"	35	70	200 / 500	VPS
	SVDLE + SV 512	FSDC / FSDR 2"	-	130	200 / 500	VPS
	SVDLE + SV 512	FSDC / FSDR 1"1/2"	70	180	200 / 500	VPS
Multicalor 200.1	VGD 40.080	Filter DN 80	-	23	700	VPS
	VGD 40.065	Filter DN 65	-	35	700	VPS
	VGD 20.503	Filter 2"	-	60	600	VPS
	SVDLE + SV 520	FSDC / FSDR 2"	45	100	200 / 500	VPS
	SVDLE + SV 512	FSDC / FSDR 2"	-	190	200 / 500	VPS
	SVDLE + SV 512	FSDC / FSDR 1"1/2"	100	260	500	VPS
Multicalor 300.1	VGD 40.100	Filter DN 100	-	22	700	VDK
	VGD 40.080	Filter DN 80	-	35	700	VPS
	VGD 40.065	Filter DN 65	-	55	700	VPS
	VGD 20.503	Filter DN 65	45	100	600	VPS
	SVDLE + SV 520	FSDC / FSDR 2"	-	170	200 / 500	VPS
	SVDLE + SV 512	FSDC / FSDR 1"1/2"	185	-	500	VPS
Multicalor 400.1	VGD 40.100	Filter DN 100	-	30	700	VDK
	VGD 40.080	Filter DN 80	-	50	700	VPS
	VGD 40.065	Filter DN 65	-	90	700	VPS
	VGD 20.503	Filter 2"	70	170	500	VPS
	SVDLE + SV 520	FSDR2"	-	300	500	VPS
	SVDLE + SV 512	FSDC / FSDR 2"	230	-	200 / 500	VPS
Multicalor 500.1	VGD 40.125	Filter DN 125	-	35	700	VDK
	VGD 40.100	Filter DN 100	-	45	700	VDK
	VGD 40.080	Filter DN 80	-	75	700	VPS
	VGD 40.065	Filter DN 65	65	140	600	VPS
	VGD 20.503	Filter 2"	-	250	600	VPS
	SVDLE + SV 520	FSDC / FSDR 2"	180	-	200 / 500	VPS
Multicalor 600.1	VGD 40.125	Filter DN 125	-	50	700	VDK
	VGD 40.120	Filter DN 100	-	60	700	VDK
	VGD 40.080	Filter DN 80	-	100	700	VPS
	VGD 40.065	Filter DN 65	90	180	600	VPS
	VGD 20.503	Filter 2"	-	340	600	VPS
	SVDLE + SV 520	FSDC / FSDR 2"1/2	170	-	200 / 500	VPS
Multicalor 700.1	VGD 40.125	Filter DN 125	-	60	700	VDK
	VGD 40.100	Filter DN 100	-	75	700	VDK
	VGD 40.080	Filter DN 80	-	140	700	VPS
	VGD 40.065	Filter DN 65	125	280	700	VPS
Multicalor 800.1	VGD 40.125	Filter DN 125	-	85	700	VDK
	VGD 40.100	Filter DN 100	-	110	700	VDK
	VGD 40.080	Filter DN 80	-	210	700	VPS
	VGD 40.065	Filter DN 65	185	410	700	VPS
Multicalor 1000.1	VGD 40.125	Filter DN 125	-	115	700	VDK
	VGD 40.100	Filter DN 100	110	165	700	VDK
	VGD 40.080	Filter DN 80	-	290	700	VPS
	VGD 40.065	Filter DN 65	250	550	700	VPS
Multicalor 1200.1	VGD 40.150	Filter DN 150	-	160	700	VDK
	VGD 40.125	Filter DN 125	-	175	700	VDK
	VGD 40.100	Filter DN 100	160	230	700	VDK
	VGD 40.080	Filter DN 80	230	420	700	VPS
Multicalor 1500.1	VGD 40.150	Filter DN 150	-	125	700	VDK
	VGD 40.125	Filter DN 125	-	150	700	VDK
	VGD 40.100	Filter DN 100	135	230	700	VDK
	VGD 40.080	Filter DN 80	225	450	700	VPS

FB-Multicalor
ate: 03-03-2008

Ecoflam

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e-mail: export@ecoflam-burners.com

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via A. Merloni, 45 - 60044 Fabriano (An) CF 01026940427"